UNIVERSITY OF CALCUTTA

Notification No. CSR/13/2026

It is notified for information of all concerned that in terms of the provisions of Section 54 of the Calcutta University Act, 1979, (as amended), and, in the exercise of his powers under 9(6) of the said Act, the Vice-Chancellor has, by an order dated 24.12.2025, approved the new revised Course Structure and syllabus of 4-year Honours & Honours with Research and 3-year MDC OF Geology under CCF, 2022.

The above shall take effect from the Odd semester examinations, 2025 and onwards.

30/01/2026

Prof.(Dr.) Debasis Das

Registrar

SENATE HOUSE

Kolkata-700073

30.01.2026

Syllabus for B.Sc. Geology

Eight Semester (Four Year) NEP System

University of Calcutta

Course Structures

Table 1: GELM (4-Year Hons. and Hons. with research)

Sem.	Paper Code	Theory	Practical	Credit			Page No.
Sem. 1	GELM-DSCC-1-Th	Introduction to Earth System Science (50)		2		4	9
	GELM-DSCC-1-P		Study of Maps, Minerals and Rocks (50)		2		10
	GELM-SEC-1	Field Studies – 1 (100)		4		4	11
Sem. 2	GELM-DSCC-2-Th	Mineral Science (50)		2		4	11
	GELM-DSCC-2-P		Crystallography & Study of minerals under microscope (50)		2		12
	GELM-SEC-2-Th	Artificial Intelligence (50)		2		4	54
	GELM-SEC-2-P		Tutorial: Artificial Intelligence (50)		2		-
Sem. 3	GELM-DSCC-3-Th	Structural Geology – 1 (50)		2		4	12
	GELM-DSCC-3-P		Graphical and stereographic methods. Study of Geological Maps. (50)		2		13
	GELM-DSCC-4-Th	Sedimentology (50)		2		4	14
	GELM-DSCC-4-P		Sedimentology Practical (50)		2		15
	GELM-SEC-3	Field Studies – 2 (100)		4		4	15

Sem. 4	GELM-DSCC-5-Th	Igneous Petrology (50)		2		4	15
	GELM-DSCC-5-P		Igneous Petrology Practical (50)		2		17
	GELM-DSCC-6-Th	Geochemistry and Economic Geology (75)		3		4	18
	GELM-DSCC-6-P		Economic Geology Practical (25)		1		19
	GELM-DSCC-7-Th	Metamorphic Petrology (50)		2		4	21
	GELM-DSCC-7-P		Study of metamorphic rocks under Microscope and Chemographic Plots (50)		2		22
	GELM-DSCC-8-Th	Palaeontology – 1 (50)		2		4	23
	GELM-DSCC-8-P		Macro palaeontology (50)		2		23
Sem.5	GELM-DSCC-9-Th	Geotectonics and Geomorphology (75)		3		4	25
	GELM-DSCC-9-P		Field Studies – 3 (25)		1		26
	GELM-DSCC-10-Th	Principles of Stratigraphy (25) and Indian Stratigraphy (50)		3		4	27
	GELM-DSCC-10-Tu		Tutorial (25)		1		-
	GELM-DSCC-11-Th	Fuel Geology (50)		2		4	28
	GELM-DSCC-11-P		Fuel Geology and Reserve Estimation (50)		2		29
	GELM-DSCC-12-Th	Hydrogeology (50)		2		4	30
	GELM-DSCC-12-P		Hydrogeology Practical (50)		2		31

Sem.6	GELM-DSCC-13-Th	Structural Geology – 2 (50)		2		4	32
	GELM-DSCC-13-P		Study of Geological Maps and Completion of Outcrops (50)		2		33
	GELM-DSCC-14-Th	Remote Sensing and GIS (50)		2		4	34
	GELM-DSCC-14-P		Application of RS and GIS in Geology (50)		2		34
	GELM-DSCC-15-Th	Engineering Geology (50)		2		4	35
	GELM-DSCC-15-P		Engineering Geology Practical (50)		2		36
	GELM-DSCC-16	Summer Internship: Earth Science (75)		3		3	37
Sem.7	GELM-DSCC-17-Th	Exploration Geology (50)		2		4	37
	GELM-DSCC-17-P		Exploration Geology Practical (50)		2		38
	GELM-DSCC-18-Th	Geophysics (50)		2		4	39
	GELM-DSCC-18-P		Numerical Application in Geology (50)		2		40
	GELM-DSCC-19-Th	Environmental Geology and Marine Geology (75),		3		4	40
	GELM-DSCC-19-P		Tutorial (25)		1		-
	GELM-DSCC-20-Th	Palaeontology – 2 (50)		2		4	42
	GELM-DSCC-20-P		Micropaleontology, Ichnology and Study of Vertebrate Teeth (50)		2		43
	GELM-DSCC-21-Th	Climatology and Planetary Geology (75)		3		4	44
	GELM-DSCC-21-P		Tutorial. (25)		1		-

Sem.8	**4-Years Honours with Research:** Research Methodology: GELM-RM-1 & GELM-RM-2. Research Internship: GELM-RI-1						
	GELM-RM-1-Th	Statistical Application in Geology (50)		2		4	46
	GELM-RM-1-P		Quantitative Petrology (50)		2		47
	GELM-RM-2-Th	Analytical Techniques in Earth Sciences (50)		2		4	47
	GELM-RM-2-P		Computer Application in Geology (50)		2		48
	GELM-RI-1-Th	Earth Science Colloquium Project/ Presentation (75)		3		4	49
	GELM-RI-1-P		Earth Science Colloquium Viva (25)	1			49
	GELM-DIS-Th	Dissertation Thesis (150)		6		8	50
	GELM-DIS-P		Dissertation Viva (50)		2		50
	4-Years Honours: Research Methodology: GELM-RM-1 & GELM-RM-2. Core Papers: GELM-DSCC-22 & GELM-DSCC-23. Review: GELM-REV-1						
	GELM-RM-1Th	Statistical Application in Geology (50)		2		4	46
	GELM-RM-1-P		Quantitative Petrology (50)		2		47
	GELM-RM-2-Th	Analytical Techniques in Earth Sciences (50)		2		4	47
	GELM-RM-2-P		Computer Application in Geology (50)		2		48
	GELM-DSCC-22-Th	Introductory soil science and Natural Hazards (75)		3		4	50
	GELM-DSCC-22-Tu		Tutorial. (25)		1		-
	GELM-DSCC-23-Th	Sustainable Watershed Management and Medical Geology (75)		3		4	52
	GELM-DSCC-23-Tu		Tutorial (25)		1		-
	GELM-REV-1-Th	Earth Science Colloquium Project/ Presentation (75)		3		4	49
	GELM-REV-1-P		Earth Science Colloquium Viva (25)		1		49

Table 2: MGEL (Minor) for 4-Years Course

Sem.	Paper Code	Theory	Practical	Credit			Page No.
Sem 1/ Sem 3	MGEL-MN-1-Th	Introduction to Earth System Science (50)		2		4	9
	MGEL-MN-1-P		Study of Maps, Minerals and Rocks (50)		2		10
Sem 2/ Sem 4	MGEL-MN-2-Th	Mineral Science (50)		2		4	11
	MGEL-MN-2-P		Crystallography & Study of minerals under microscope (50)		2		12
Sem.5/ Sem.6	MGEL-MN-3-Th	Structural Geology – 1 (50)		2		4	12
	MGEL-MN-3-P		Graphical and stereographic methods. Study of Geological Maps. (50)		2		13
	MGEL-MN-4-Th	Igneous Petrology (50)		2		4	15
	MGEL-MN-4-P		Igneous Petrology practical (50)		2		17

Table 3: Interdisciplinary Course (IDC)

GELD-1-Th	Earth Systems Science (50)		2		3	53
GELD-1-Tu		Project work (25)		1		54

Table 4: MGEL CC (MDC) for 3-Years Couse

Sem.	Paper Code	Theory	Practical	Credit			Page No.
Sem.1	MGEL-CC-1-Th	Introduction to Earth System Science (50)		2		4	9
	MGEL-CC-1-P		Study of Maps, Minerals and Rocks (50)		2		10
Sem.2	MGEL-CC-2-Th	Mineral Science (50)		2		4	11
	MGEL-CC-2-P		Crystallography & Study of minerals under microscope (50)		2		12
Sem.3	MGEL-CC-3-Th	Structural Geology – 1 (50)		2		4	12
	MGEL-CC-3-P		Graphical and stereographic methods. Study of Geological Maps. (50)		2		13
Sem. 1/2/3	MGEL-SEC-1-P	Field Studies – 1 (100)				4	11
Sem.4	MGEL-CC-4-Th	Igneous Petrology (50)		2		4	15
	MGEL-CC-4-P		Igneous Petrology Practical (50)		2		17
	MGEL-CC-5-Th	Sedimentology (50)		2		4	14
	MGEL-CC-5-P		Sedimentology Practical (50)		2		15

Sem.5	MGEL-CC-6-Th	Metamorphic Petrology (50)		2		4	21
	MGEL-CC-6-P		Study of metamorphic rocks under microscope, chemographic plots (50)*		2		22
	MGEL-CC-7-Th	Geochemistry and Economic Geology (75)*		3		4	18
	MGEL-CC-7-P		Economic Geology Practical (25)		1		19
Sem.6	MGEL-CC-7-Th	Metamorphic Petrology (50)		2		4	21
	MGEL-CC-7-P		Study of metamorphic rocks under microscope, chemographic plots (50)*		2		22
	MGEL-CC-8-Th	Palaeontology – 1 (50)		2		4	23
	MGEL-CC-8-P		Macro Palaeontology (50)		2		23
	***CC-1 for Sem 5 and CC-2 for Sem 6**						

Table 5: MGEL Minor (MDC) for 3-Years Course

Sem.	Paper Code	Theory	Practical	Credit			Page No.
Sem.3	MGEL-MN-1-Th	Introduction to Earth System Science (50)		2		4	9
	MGEL-MN-1-P		Study of Maps, Minerals and Rocks (50)		2		10
	MGEL-SEC-1-P	Field Studies – 1 (100)				4	11
Sem.4	MGEL-MN-2-Th	Mineral Science (50)		2		4	11
	MGEL-MN-2-P		Crystallography & Study of minerals under microscope (50)		2		12
Sem.5	MGEL-MN-3-Th	Structural Geology – 1 (50)		2		4	12
	MGEL-MN-3-P		Graphical and stereographic methods. Study of Geological Maps. (50)		2		13
	MGEL-MN-4-Th	Igneous Petrology (50)		2		4	15
	MGEL-MN-4-P		Igneous Petrology Practical (50)		2		17
Sem.6	MGEL-MN-5-Th	Sedimentology (50)		2		4	14
	MGEL-MN-5-P		Sedimentology Practical (50)		2		15
	MGEL-MN-6-Th	Metamorphic Petrology (50)*		2		4	21
	MGEL-MN-6-P		Study of metamorphic rocks under Microscope and Chemographic Plots (50)*		2		22

Tutorial (25 marks)*: Evaluation of all tutorial papers will be based on report of project work.*

Introduction to Earth System Science

(Full Marks – 50)

1. **Earth Systems Science**: Definitions and Scope.

2. **Elementary ideas on solar system:** terrestrial and Jovian planets. Origin of the solar system, nebular hypothesis, formation of planets. Layered structure of Earth, differentiation of Earth's core, mantle and crust, formation of Earth's oceans and atmosphere. Earth's magnetic field and its origin (geodynamo). Earth as a system of interacting components-solid earth, atmosphere, hydrosphere, biosphere.

3. **History of development of geological thoughts**, Catastrophism, Neptunism, Plutonism, Uniformitarianism, law of superposition, law of faunal succession, law of original horizontality and law of cross-cutting relation. Contribution of Werner, Hutton, Smith and Lyell.

4. **Earth's materials**: **Minerals**. Definition of minerals. Chemical classification of minerals: native elements, oxides, sulphides, carbonates, sulphates, phosphates, silicates (a few examples from each class). Chemical compositions and physical properties of some common rock forming minerals and ore minerals (those mentioned in the Unit 1 of the practical paper: GELM/MGEL-DSCC-1-P).

5. **Earth's materials: Rocks**. Rocks as mineral assemblages, rock texture. Rock cycle.

   Igneous rocks, Forms and structure, modes of emplacement. acid, intermediate, mafic and ultramafic rocks. Petrography of granite, granodiorite, pegmatite, rhyolite, syenite, trachyte, diorite, andesite, gabbro, dolerite, basalt, peridotite.

   Sedimentary rocks, clastic and non-clastic. Petrography of conglomerate, sandstone, siltstone, shale, limestone,

   Metamorphic rocks, foliated, non-foliated. Petrography of slate, phyllite, schist, gneiss, quartzite, marble.

6. **Structure of geologic bodies**. Deformation of rocks. Primary and secondary structures: definitions, brief outlines, and examples.

   Stratum: formation, group and bed, volcanic flows.

   Attitudes of linear and planar structures: strike and dip, plunge and pitch.

   Definitions, brief descriptions and labelled diagrams of the following structures:

   - Folds: antiform, synform, neutral fold, anticline, syncline.
   - Fractures: joints veins, and faults. Normal, reverse, and strike slip faults.
   - Foliations and lineations.

7. **Earth's internal processes**: Magmatism, metamorphism. Volcanoes and volcanism, products of volcanic eruption, eruptive styles, volcanic belts, recent volcanism in India.

   Earthquakes: causes, elastic rebound theory, focus and epicentre, intensity and magnitude. Seismic waves, seismograms, travel-time curves for seismic waves, seismic discontinuities, locating epicentre, and determining magnitude. Earthquake belts. Effects of earthquakes, seismic zones of India.

8. **Internal Constitution of Earth:** Evidences from seismic waves, meteorites, and others. Compositional layers: crust, mantle and core, their sublayers and bounding discontinuities. Rheological layers: lithosphere, asthenosphere, mesosphere.

9. **Heat flow:** Basic concepts, geothermal gradient. Hotspot and mantle plume.

10. **Elementary idea of theory of plate tectonics**. Plates and plate boundaries, relative motion of plates. Present day configuration of plates.

11. **Earth's surface processes.** Weathering, erosion, mass wasting; bed rock, regolith, soil, soil profile. Erosion, transportation and deposition by wind, river, glacier, groundwater and ocean. Common landforms related to action of wind, river, glacier; coastal landform. Ice ages, evidence and causes. Oceanic and atmospheric circulation patterns.

12. **Age of the Earth**. Principles of determination of relative ages of rock bodies and geologic events. Absolute ages of rocks and minerals, fundamental principles of radiometric dating. Geologic Time Scale up to the level of Eras and Periods.

13. **The fossil records**. Fossils as evidence of past life. Modes of preservation of fossils. Uses of fossils.

Study of Maps, Minerals and Rocks

(Full Marks – 50)

Unit 1. Study of topographic map

Detailed study of topographic sheets and preparation of physiographic description of an area.

Study of major geomorphic features and their relationships with outcrops through maps and physiographic models.

Unit 2. Study of common minerals in hand specimens

Silicates: garnet, sillimanite, kyanite, staurolite, tourmaline, talc, chlorite, biotite, muscovite, feldspar, quartz (different varieties), jasper, agate.

Other minerals: pyrite, chalcopyrite, galena, sphalerite, calcite, dolomite, malachite, magnetite, haematite, psilomelane and pyrolusite, bauxite, apatite, graphite, barite and gypsum.

Unit 3. Study of common igneous, metamorphic and sedimentary rocks in hand specimens

Granite, granodiorite, diorite, syenite, nepheline syenite, gabbro, anorthosite, peridotite, pyroxenite, basalt, andesite, trachyte, rhyolite and pegmatite.

Sandstone, shale, limestone, dolomite, ironstone, conglomerate.

Slate, phyllite, schist, gneiss, amphibolite and marble.

Reference Books

- Duff, P. M. D. and Duff, D. (Eds.) (1993). Holmes' principles of physical geology.
- Emiliani, C. (1992). Planet Earth: cosmology, geology, and the evolution of life and environment. Cambridge University Press.
- Grotzinger, J., Jordan, T.H., Press, F and Siever, R. (2007). Understanding Earth (Fifth Edition). W. H. Freeman and company, New York. Other editions of this book may also be consulted.
- Klein, C. (2007). Manual of Mineral Science. 23rd Edition. J. Wiley and Sons. (For unit 4)

- Lutgens, F. K., Tarbuck, E. J., and Tasa, D. (2016). Essentials of Geology. 13th Edition. Pearson Education, Inc. Other editions of this book may also be consulted.
- Tarback, E. J. and Lutgens, F.K. (2006). Earth Science. Pearson Prentice Hall, New Jersey.

Field Studies – 1

(Full Marks – 100)

A 7-days fieldwork. Introductory fieldwork for reconnaissance geological survey of an area. Reading of topographic maps and use of geological field equipment. Report writing.

Fieldwork should be carried out in and around following areas:

Maithan, Purulia, Biharinath and Saltora areas of West Bengal, Jabalpur area of M.P., Chandipur-Balasore area of Odisha, Arialur-Chennai of Tamil Nadu.

Evaluation will be based on field performance, field notebook records, report writing, and a viva-voce examination.

Mineral Science

(Full Marks – 50)

Unit 1: Crystallography

Concept of crystal and crystalline matter. Internal order in crystal.

Crystal structure; elementary ideas about crystal morphology in relation to internal structures.

Crystal parameters and indices; form and zone.

Stereographic projection of crystal faces, Crystal symmetry, classification of crystals into systems. Lattice theory and 32 point groups. International symbol of point groups.

Twinning in crystals. Laws of twinning, Twin laws for quartz and feldspar.

Unit 2: Atomic arrangements and Mineral structure

Arrangement of atoms and ions in the minerals. Unit cell, crystal lattice, short range and long-range order – definitions and brief descriptions.

Different types of bonding in minerals.

Co-ordination principle, ionic radius and coordination number. Pauling's rules.

Basic concepts of solid solutions, polymorphism (with descriptions of polymorphs of C, SiO_2, Al_2SiO_5, $CaCO_3$, and K-Feldspar), polytypism, isomorphism and pseudomorphism of minerals.

Arrangement of $[SiO_4]^{4-}$ tetrahedra in the silicate sub-classes: nesosilicate, sorosilicate, inosilicate (single and double chain), cyclosilicate, phyllosilicate and tectosilicate.

Internal structures of three silicate minerals groups: pyroxene, amphibole, and mica.

Unit 3: Crystal Optics

Nature of light and optical behaviour of crystals.

Introduction to petrological microscope.

Theory of light propagation in isotropic, uniaxial, and biaxial crystals.

Study of refractive indices, Becke test, twinkling effects, and pleochroism of minerals.

Principles of orthoscopic and conoscopic studies of minerals under optical microscope.

Unit 4: Introduction to X-ray crystallography

Bragg Equation and its application. Principles of single crystal X-ray diffraction and x-ray powder diffraction.

Unit 5: Fundamentals of Crystal Field Theory.

Concept of stabilization energy. Application of crystal field Theory in determining mineral structure.

Crystallography & Study of Minerals under Microscope

(Full Marks – 50)

Study of the symmetry of crystals. Stereographic projection of crystals.

Derivation of structural formulae based on composition: Pyroxene and Amphibole (on the basis of total FeO).

Study of optical properties of common rock-forming minerals: quartz, orthoclase, microcline, plagioclase, perthite, nepheline, olivine, orthopyroxene, clinopyroxene, hornblende, staurolite, garnet, muscovite, biotite, calcite, chlorite, epidote, kyanite, sillimanite, tourmaline, zircon, sphene, zoisite, apatite.

Determination of scheme of pleochroism and extinction angles of hornblende.

Reference Books

- Blackburn W. H. and W. H. Dennen. Principles of mineralogy. Dubuque, IA: Wm. C. Brown Publishers. 1993)
- Dana, E.S. and Ford, W.E., (2002) A textbook of Mineralogy (Reprints).
- Deer, W. A., Howie, R. A., and Zussman, J. (1996). An Introduction to Rock-Forming Minerals. Prentice Hall.
- Kerr, B.F., (1995) Optical Mineralogy 5th Ed. McGraw Hill, New York.
- Klein, C. (2007). The 23rd Edition of the Manual of Mineral Science (after James D. Dana). J. Wiley and Sons.
- Nesse, W. D. (2011). Introduction to Optical Mineralogy (Fourth Edition). Oxford University Press.
- Nesse, W. D. (2017). Introduction to Mineralogy (Third Edition). Oxford University Press.
- Perkins, D. (2015). Mineralogy (Third Edition). Pearson Education.
- Putnis, A. (1992). Introduction to Mineral Sciences. Cambridge University Press.
- Rutley's Elements of Mineralogy. Springer; 27th edition (November 30, 1988)
- Verma, P. K. (2010). Optical Mineralogy (Four Colour). Ane Books Pvt Ltd.

Structural Geology – 1

(Full Marks – 50)

Unit 1. Introductory Concepts: Geological structures and structural elements. Scales of observation of structures. Penetrative and non-penetrative structural elements. Definitions of geometric, kinematic and dynamic analysis of structures. Definitions and brief descriptions: primary, penecontemporaneous, and secondary structures. Application of primary structures in structural geology.

Attitudes of linear and planar structural elements: plunge and pitch, strike and dip. Representation of planes and lines in stereographic and equal area projection diagrams. Outcrops of planes on horizontal and uneven surfaces. Outlier and inlier.

Unit 2. Folds: Geometry of a fold: Fold axis, hinge line, inflection line, axial surface, median surface and enveloping surface, fold wavelength and amplitude.

Classification of folds based on direction of convexity, younging direction of beds, fold shape, orientation of fold axis and axial plane. Equal area projection diagrams of different types of folds. Concept of π and β plots. Ramsay's classification of folds (1967). Outcrops of folded rock units on horizontal and sloping surfaces. Relation between major folds and minor folds.

Unit 3. Foliations and Lineations: Primary and secondary foliation. Morphological features of secondary foliation, morphological classification of rock cleavage. Relation of cleavage and schistosity to major folds.

Types of lineation, and their geometrical relation to folds.

Unit 4. Brittle deformation structures: Different types of fracture: extension fractures/tensile cracks, sliding/in-plane fractures, tearing/out-of-plane fractures, mixed mode fractures.

Joint sets and joint systems, relation of joints to folds.

Faults: translational and rotational faults, slip and separation; nomenclature of faults based on geometrical relation of faults to affected strata, slip and separation.

Effects of faults on outcrop of strata.

Horst and graben, autochthon, allochthon, nappe, window and klippe.

Criteria for recognition of faults.

Unit 5. Unconformity: Types of unconformities, criteria for distinguishing unconformity from faults and intrusive contacts.

Graphical and stereographic methods. Study of Geological Maps

(Full Marks – 50)

Unit-1. Graphical and stereographic methods

Graphical solution of simple true dip-apparent dip problems, determination of attitudes of homoclinal strata from vertical bore hole data.

Determination of slip and separation of faults using graphical methods.

Stereographic projection of planes and lines. Solution of simple structural problems using a stereographic net, e.g., true dip-apparent dip problems, determination of plunge and pitch of lines.

Determination of the structural elements of cylindrical folds using stereonet.

Unit-2. Study of Geological Maps-1

Study of geological maps on horizontal and uneven topographic surfaces, of regions with deformed lithounits. [homoclinal strata, unconformities, cylindrical folds, faults (excluding rotational faults and thrust faults)].

Reference Books

- Billings, M. P. (1987). Structural Geology, 4th edition. Prentice-Hall.
- Davis, G. H., Reynolds, S. J., and Kluth, C. F. (2012). Structural Geology of Rocks and Region. 3rd Edition. John Wiley & Sons, Inc.
- Fossen, H. (2016). Structural Geology. Second Edition. Cambridge University Press.
- Lisle, R. J. and Leyshon, P. R. (2004) Stereographic projection techniques for structural geologists and civil engineers. Second Edition. Cambridge University Press.
- Marshak, S. and Mitra, G. (1988). Basic Methods in Structural Geology. Prentice Hall.
- Phillips, F. C. (1973). The use of stereographic projection in structural geology. Hodder.
- Ragan, D. M. (2009). Structural Geology: an introduction to geometrical techniques (4th Ed). Cambridge University Press (For Practical)
- Twiss, R. J. and Moores, E. M. (2007) Structural Geology. Second Edition. W. H. Freeman and Company.

Sedimentology

(Full Marks – 50)

Unit 1: Introduction to Sedimentology

Scope of sedimentology, origin of sediments, classification of sedimentary rocks based on composition and texture.

Unit 2: Granulometry: Textural parameters of clastic sediments

Grain size: concept of size and scale; particle shape and fabric; sedimentary textures. grain size analyses and environmental connotations.

Unit 3: Basic Hydraulics and Sedimentary Structures: sediment transport mechanism

Fluid flow: flow rheology, fluid gravity flow, sediment gravity flow, flow regime, laminar and turbulent flow, particle entrainment in fluid flow.

Mass flow: types and deposits

Sedimentary structure: primary and penecontemporaneous deformation structures, biogenic structures.

Paleocurrent analysis: data acquisition, methodology, different palaeocurrent patterns.

Unit 4: Sedimentary rocks

Siliciclastic rocks: components and classification(s) of conglomerates, sandstones, mudrocks.

General introduction to carbonate rocks, BIF, chert;

Components and classifications of limestone, dolomites and dolomitisation.

Unit 5: Diagenesis

Concepts of diagenesis

Stages of diagenesis: diagenetic changes in sand and carbonate deposits, lithification.

Unit 6: Sedimentary environments

Classification, sedimentary facies.

Facies models for glacier, meandering, fluvial, deltaic, and shelf depositional settings

Facies analysis: Principles, facies models and environmental reconstructions of principal siliciclastic environments in continental (aeolian, glacial, fluvial, lacustrine), transitional and marine realm (deltaic, estuarine, tidal flat, barrier beach). Carbonate depositional system.

Unit 8: Basin analysis and Sequence Stratigraphy

Sedimentary basins in different tectonic setup.

Sequence Stratigraphy: Concepts, Systems Tracts, Boundaries, Surfaces, Parasequences, Hierarchy, Sea-Level Changes and Hydrocarbon Applications.

Sedimentology Practical

(Full Marks – 50)

Study of sedimentary structures in hand specimen.

Petrographic study of clastic and non-clastic rocks in thin sections under microscope and interpretation of possible depositional environment.

Trend data analysis.

Reference Books

- Allen, J.R.L. (1985). Principles of Physical Sedimentology. George Allen and Unwin, London.
- Collinson, J., Mountney, N., Thompson, D. (2006) Sedimentary Structures, Terra Publishing, 3rd Edn.,
- Folk, R. L. (1974). Petrology of Sedimentary Rock. Hemphill Publishing Company, Austin, Texas.
- Nichols, G. (2009). Sedimentology and Stratigraphy. Second Edition. Wiley Blackwell.
- Prothero, D. R. and Schwab, F. (2004). Sedimentary geology. Macmillan.
- Selley, R.C., Applied sedimentology, 2nd Edn., Academic Press, 2000
- Tucker, M. E. (2001). Sedimentary Petrology, Third Edition Blackwell Science.
- Sengupta, Supriya. Introduction to sedimentology. Routledge, 2017.

Field Studies – 2

(Full Marks – 100)

12-day fieldwork for lithological and structural mapping of a deformed rock terrain and sedimentological studies of adjoining area.

Fieldwork should be carried out in and around following areas:

Ramtek-Mansar area of Maharashtra, Ajmer, Nathdwara-Kankrouli, Bewar and Jahazpur areas of Rajasthan, Ghatshila-Galudih area of Jharkhand and Chitradurga area of Karnataka.

Evaluation will be based on field performance, field notebook records, report writing, and a viva-voce examination.

Igneous Petrology

(Full Marks – 50)

Unit 1: Introduction to Igneous Petrology

Modes of magma generation in the crust and upper mantle.

Physical properties of magma - temperature, viscosity, density and volatile content. Modes of emplacement of igneous rocks: volcanic, hypabyssal, and plutonic.

Unit 2: Forms of Igneous rock bodies

Mode of occurrence of igneous rocks.

Forms and structures of igneous rock bodies.

Unit 3: Texture and Microstructure of Igneous rocks

Crystallinity, granularity, shapes and mutual relations of grains; nucleation and growth of igneous minerals.

Description of the following textures and microstructures with their occurrence in different rocks - panidiomorphic, hypidiomorphic, allotriomorphic, porphyritic, vitrophyric, poikilitic, ophitic, sub-ophitic, intergranular, intersertal, pilotaxitic, trachytic, graphic, granophyric, rapakivi, orbicular, corona and keliphitic rims, perthitic, myrmekitic, variolitic, speherulitic and spinifex, vesicular, amygdaloidal, flow structures such as pilotaxitic and trachytic.

Unit 4: Classification of Igneous rocks and Petrographic Description

Bases of classification of igneous rocks: mineralogical, textural, chemical, chemico-mineralogical, associational and tectonic.

Norm and mode. Standard classification schemes – Shand, Hatch and Wells, and IUGS. TAS diagram for volcanic rocks. Outline of CIPW classification.

Composition and texture and Indian occurrence of important igneous rocks: granite, pegmatite, syenite, monzonite, diorite, norite, gabbro, anthrothosite, dolerite, pyroxenites, peridotite, lamprophyres, carbonatite, rhyolite, andesite, dacite, basalt, komatiite.

Pyroclastic rocks.

Unit 5: Chemical Petrology

Major, minor, trace and REE; Variation diagrams and its use in magmatic evolution. Concept of K_d, and D.

Unit 6: Phase Diagrams

Phase rule and its application to eutectic, peritectic and solid solution system. Phase equilibria in the following binary and ternary systems, and their petrogenetic significance: diopside – anorthite, forsterite – silica, albite –anorthite, albite – orthoclase, diopside – albite – anorthite, anorthite – forsterite –silica, albite – orthoclase - silica, forsterite – diopside – silica and nepheline - kalsilite - silica.

Bowen’s reaction principle.

Unit 7: Petrogenesis of Igneous rocks

Magmatic processes; mantle melting and melt-mantle interaction, crystal settling in magma, magma convection, crystal mush theory, igneous cumulates, magmatic differentiation and diversity of igneous rocks, assimilation and fractional crystallisation.

Petrogenesis of common igneous rocks: granite, basalt, anorthosite, alkaline rocks, carbonatite and ultramafic rocks.

Unit 8: Magmatism and Tectonic setting

Fundamental ideas of magmatism in different tectonics settings, mantle convection.

Magmatic evolution in various geodynamic settings.

Mid Ocean Ridge Basalt (MORB) and Island Arc Basalt (IAB), Oceanic Island Basalt (OIB), and Continental Flood Basalt (CFB).

Large Igneous Provinces, mantle plumes and related magmatism with special emphasis on Deccan Trap.

Brief idea on physical volcanology, criteria for identification of several volcanic flows, distinct zones within a flow, common volcanic structures, pyroclasts.

General idea on layered complex, salient features of Stillwater, Skaergaard and Bushveld complexes.

Ophiolites: genesis, emplacement and classification

Igneous Petrology Practical

(Full Marks – 50)

Study of important igneous rocks in thin sections: granite, granodiorite, diorite, syenite, nepheline syenite, gabbro, anorthosite, dunite, peridotite, pyroxenite, basalt, andesite, trachyte, rhyolite, dacite.

Plotting of mode in IUGS classification of igneous rocks (Streckeisen diagram).

Calculation of CIPW norms of silica-oversaturated and undersaturated igneous rocks, use of those normative data to interpret crystallization history.

Determination of igneous rock suite using variation diagrams. Construction of spider diagram and identification of different elemental anomalies from trace-element and REE spider diagrams.

Reference Books

- Best, Myron G. (2001). Igneous and Metamorphic Petrology.
- Blatt H., Tracy R.J. and Owens B.E. (2006) Petrology – Igneous, sedimentary and metamorphic rocks (3rd Edition), W.H. Freeman and Company, New York.
- Bose, M.K., 1997: Igneous Petrology. The World Press Pvt. Ltd. 568 p.
- Cox, K. G. and Bell. J. D. (1979). The Interpretation of Igneous Rocks. Springer/Chapman and Hall.
- Ehlers, WG, and Blatt, H. (1987) Petrology, Igneous, Sedimentary and Metamorphic rocks, CBS Publishers
- Frost B. R. and Frost C. D (2014). Essentials of Igneous and Metamorphic Petrology. Cambridge University Press.
- Hall, A. Igneous Petrology, 2nd Edn., Longman, 1996
- Hatch F.H., Wells A.K and Wells M.K. (1984) Petrology of the igneous rocks. CBS Publishers, 551p.
- McBirney, A. R. Igneous Petrology, 3rd Edn., Jones & Bartlett, 2006
- Philpotts, A. and Ague, J. (2009). Principles of igneous and metamorphic petrology. Cambridge University Press.

- Rollinson, H. R. (2014). Using geochemical data: evaluation, presentation, interpretation. Routledge.
- Sen, G. 2014, Petrology: Principles and Practice, Springer.
- Turner F.J and Verhoogen J. (1960) Igneous and Metamorphic Petrology, McGraw- Hill.
- Winter, J. D. (2014). Principles of igneous and metamorphic petrology. Pearson.

Geochemistry and Economic Geology

(Full Marks – 75)

Group-A: Geochemistry

(Full Marks – 35)

Unit 1: Origin of Solar System: Origin of Solar System; Nucleosynthesis; Origin and evolution of the Earth; Origin of the Earth's crust.

Definition, age, importance of study; classification and its basis, mineralogical characteristics and contrast with terrestrial mineralogy, broad chemical characteristics, brief outline on origin.

Unit 2: Layered Structure of Earth and Geochemistry: Chemical Composition of the Earth as three-layer structures.

Composition of crust, mantle and core.

Unit 3: Aqueous Geochemistry: Abundance of elements in river and ocean water, constancy of elemental composition of ocean water

Concept of ionic and redox potential and pH

Aqueous geochemistry- basic concepts and speciation in solutions, Eh, pH relations.

Factors controlling chemical sedimentation.

Unit 4: Geochemical Classification of Elements: Goldschmidt's Rule; Behaviour of elements during magmatic crystallization. Rare Earth Elements (REE) Geochemistry – distribution patterns, fractionation, and geologic significance.

Unit 5: The atmosphere: structure and composition of atmosphere; geochemical cycle of nitrogen. The evolution of atmosphere; constancy of atmospheric composition; Formation and destruction of ozone layer, Ozone hole.

Unit 6: Isotope Geology: Principles and methods of isotope geochemistry, Systematics of Stable (O, H, C, N and S) and radioactive (Rb-Sr, Sm-Nd, K-Ar, U-Pb and C-14) isotopes, cosmogenic isotopes; Application of isotopes in Geology.

Unit 7: Chemical Geodynamics: Chemical evidence for mantle heterogeneity, including depleted mantle (DM), enriched mantle (EM-I & EM-II), HIMU and PREMA. Lead paradox, DUPAL anomaly.

Unit 8: Geochemical cycle: Geochemical cycles of Oxygen, Nitrogen, Carbon and Sulphur.

Group – B: Economic Geology

(Full Marks – 40)

Unit 1: Ores and Gangues

Ores, protore, gangue minerals, tenor, grade and lodes. Hypogene and supergene ore deposits, epigenetic and syngenetic mineral deposits; mineral beneficiation. Resources and reserves-economic and academic definitions.

Unit 2: Ore – Classification, Types and Genesis of Ore

Endogenous processes: magmatic process, skarns, greisens, and hydrothermal deposits.

Exogenous processes: sedimentary processes, oxidation and supergene enrichment, placer deposits.

Unit 3: Mineral deposits in Space and Time

Mineral deposits and their litho-tectonic environments.

Metallogenic provinces and epochs.

Unit 4: Ore texture

Types of ore texture, sequence of temperature of formation of ore minerals, ore solid solution, complexing and ore deposition.

Unit 5: Ore grade and Reserve

Assessment of ore grade and reserve, reserve estimation.

Unit 6: Metallic and Nonmetallic Deposits of India

Important deposits of India including atomic minerals: study of geologic set up, mode of occurrence, mineralogy and genesis of the following ore deposits in India: iron ore in Singhbhum and Karnataka, Manganese of Central India, copper of Malanjkhand, lead-zinc of Zawar area, uranium of Singhbhum.

Non-metallic and industrial rocks and minerals in India (e.g. mica, limestone, gypsum, asbestos, granite, marble, and sandstone).

Introduction to gemmology.

Strategic, Critical and Rare Earth Elements (REEs) – Importance, distribution in India, and their economic significance.

Unit 7: Mineral Economics

Resource management concept and mineral economics. Present status of resources.

Basic outline of National Mineral Policy and Legislation in India.

Economic Geology Practical

(Full Marks – 25)

- Hand specimen study of distinguishing properties of important ores and economic minerals. Study of macroscopic ore texture in polished hand specimen.
- Ore microscopy: Mineral identification (common oxides and sulphides), Mineral association, Broad textural features, Paragenesis.

Reference Books

Group – A

- Albarède, F. (2003). Geochemistry: an introduction. Cambridge University Press.
- Dickins, A. P., Radiogenic Isotope Geology. Cambridge University Press, 1995
- Faure, G., 1986: Principles of Isotope Geology-John Wiley
- Faure, Gunter and Teresa M. Mensing (2004). Isotopes Principles and Applications. Wiley India Pvt. Ltd
- Geyh, M. A. and Schleicher, H., Absolute age determination. Springer,1990
- Govett, G.J.S. (Ed.), 1983: Handbook of Exploration Geochemistry-Elsevier
- Henderson, P., 1987: Inorganic Geochemistry-Pergamon Press.
- Hoefs, J., Stable Isotope Geochemistry, 3rd Edn. Springer-Verlag, 1987
- Krauskopf, K.B., 1967: Introduction to Geochemistry-McGraw Hill
- Longman U.K. Faure, G., Principles of Isotope Geology, 2nd Edn. John Wiley & Sons, 1986
- Marshal, C.P. and Fairbridge, R.W., 1999: Encyclopaedia of Geochemistry-Kluwer Academic
- Mason, B. and Moore, C.B., 1991: Introduction to Geochemistry-Wiley Eastern
- Misra, K.C. 2012, Introduction to Geochemistry: Principles and Applications, Wiley-Blackwell.
- Rollinson, H. (2007). Using geochemical data – evaluation, presentation and interpretation. 2nd Edition. Publisher Longman Scientific and Technical.
- Sharp Zachary (2006). Principles of Stable Isotope Geochemistry. Prentice Hall
- Walther, J. V. (2009). Essentials of geochemistry. Jones & Bartlett Publishers
- White, M. William (2014). Isotope Geochemistry. Wiley – Blackwell

Group – B

- Arndt, Nicholas and Ganino, Clément 2012, Metals and Society – An Introduction to Economic Geology - Springer, Heidelberg, 160pp.
- Bateman, A.M. and Jensen, M.L. (1990). Economic Mineral Deposits. John Wiley.
- Craig J.R. and Vauhan, D.J. 1994, Ore Microscopy and Ore Petrography –. John Wiley and Sons, 434pp.
- Deb, S. (1980). Industrial minerals and rocks of India. Allied Publishers.
- Evans, A.M. (1993). Ore Geology and Industrial minerals. An Introduction. (Third Edition). Blackwell Publishing.
- Guilbert, John M. and Charles Frederick Park (2007) The Geology of Ore Deposits, Waveland Press
- Krishnaswamy, S. (1979) India's mineral resources. Oxford & IBH
- McDonald, I. Boyce A.J., Butler I.B., Herrington R.J. and Polys D.A. (Eds), 2005, Mineral Deposits and Earth Evolution –The Geological Society of London. 269pp.
- Mookherjee, A. (1999): Ore Genesis – A Holistic Approach. Allied Publishers Ltd., New Delhi, India. 657p.
- Piranjo, F. 2012. Hydrothermal Mineral Deposits: Principles and Fundamental Concepts for the Exploration Geologist – Springer Science & Business Media, 709pp.

- Prasad, U. (2006) Economic Geology: Economic Mineral Deposits. CBS Pub.
- Ridley, J. (2013): Ore Deposit Geology. Cambridge University Press, UK. P398.
- Robb, Lawrence 2005, Introduction to Ore Forming Processes –Blackwell Publishing Company, Victoria, 373pp.
- Sarkar, S.C. and Gupta, A. (2014) Crustal Evolution and Metallogeny in India. Cambridge Publications.
- Sawkins, F.J. 2013. Metal deposits in relation to plate tectonics –Springer Science & Business Media, 461pp.
- Stanton, R. L. (1972). Ore Petrology. McGraw-Hill, 713pp.
- Tiwari, S.K. (2010) Ore Geology, Economic Minerals and Mineral Economics, Atlantic Publishers & Distributors (P) Limited

Metamorphic Petrology

(Full Marks – 50)

Unit 1: Metamorphism: Controls and Types

Definition of metamorphism. Factors controlling metamorphism, Types of metamorphism – contact, regional, fault zone metamorphism, impact metamorphism.

Unit 2: Metamorphic Facies and Grades. Metamorphic Structures and Textures

Index minerals, metamorphic zones and isograds.

Concept of metamorphic facies and grade; Facies series.

Unit 3: Structures and Textures of Metamorphic Rocks

Structure and texture; relationship between metamorphism and deformation.

Unit 4: Metamorphic Equilibrium

Stable mineral assemblages.

Closed and open system.

Composition-paragenesis diagrams. ACF, AKF and AFM diagrams.

Unit 5: Fundamentals of thermodynamics used in Geological system

Phase rule, metamorphic reactions and phase equilibria in metamorphic rocks. Metamorphic phase equilibria calculation: geothermometry and geobarometry. Phase diagrams, Schreinemakers bundle and petrogenetic grid for metamorphic assemblages in various grades of metamorphism. Graphical representation of various mineral assemblages in different P-T conditions.

Unit 6: Progressive and Retrogressive Metamorphism

Metamorphism of Mafic, Pelitic and Calcareous Rocks.

Progressive and retrogressive metamorphism.

Prograde and retrograde metamorphic minerals reactions.

Unit 7: Migmatites and their origin

Migmatites, its origin and evidence.

Metamorphic differentiation.

Unit 8: Metasomatism

Metasomatism, Alkali metasomatism.

Unit 9: Metamorphic rock associations and Plate Tectonic settings

Heat flow and metamorphism; Paired Metamorphic belt, Schematic diagrams to illustrate the origin of paired metamorphic belts. Time-scale of metamorphism and implications on thermal history. Temperature-time histories in metamorphic rocks. Metamorphic P-T-t paths and tectonic evolution. Thermal modelling and metamorphic facies series. Different types of metamorphic facies and their tectonic setting.

Regional occurrence and tectonic significance of metamorphic rocks: metamorphism along convergent plate margins, in continent-continent collisions, in rifting terrains and sea floor metamorphism.

Study of Metamorphic Rocks under Microscope and Chemographic Plots

(Full Marks – 50)

- Textural and mineralogical study of following metamorphic rocks in thin sections: slate, schists (pelitic and mafic), gneiss, amphibolite, charnockite, khondalite, mafic granulite, eclogite, calc-silicates, marble, high Mg-Al granulites.
- Interpretation of metamorphic textures with reference to time relations between the phases of deformation and recrystallization of minerals such as chloritoid, garnet, staurolite, kyanite and magnetite.
- Interpretation of protolith, grade and facies; important reaction texture under microscope.
- Graphical plots of metamorphic mineral assemblages using chemographic diagrams (ACF and AKF and AFM).

Reference Books

- Best, M.G., 2003, Igneous and Metamorphic Petrology, Blackwell.
- Frost, B.R. and Frost, C.D. 2019, Essentials of Igneous and Metamorphic Petrology, Cambridge University Press.
- Kornprobst, Jacques 2002, Metamorphic Rocks and Their Geodynamic Significance, Springer.
- Philpotts, A. and Ague, J. (2009). Principles of igneous and metamorphic petrology. Cambridge University Press.
- Raymond, L. A. (2002). Petrology: the study of igneous, sedimentary, and metamorphic rocks. McGraw-Hill Science Engineering.
- Rollinson, H. R. (2014). Using geochemical data: evaluation, presentation, interpretation. Routledge.
- Sharma, Ram S. (2016) Metamorphic Petrology Concepts and Methods. Text Book Series, Geological Society of India, Bangalore
- Spear F. S. (1993). Metamorphic phase equilibria and Pressure-Temperature-Time paths. Mineralogical Society of America. Monograph.
- Winter, J. D. (2014). Principles of igneous and metamorphic petrology. Pearson.

Palaeontology – 1

(Full Marks – 50)

Unit 1: Fossilization and fossil record

Nature and importance of fossil record; Fossilization processes and modes of preservation.

Unit 2: Taxonomy and Species concept

Species concept with special reference to palaeontology, Taxonomic hierarchy Theory of organic evolution interpreted from fossil record.

Introduction to ecology and palaeoecology with case studies.

Taphonomic principles with case studies.

Unit 3: Invertebrates

Hard part morphology of Anthozoa, Mollusca, Brachiopoda, trilobites and echinoids.

Significance of ammonoids in Mesozoic biostratigraphy and their paleobiogeographic implications.

Functional adaptation of Bivalvia.

Origin of invertebrates and major steps in their evolution.

Unit 4. Paleobotany and Introduction to Gondwana Flora

Plant diversity through time; flowering versus non-flowering plants; palynology as a tool; Gondwana flora and importance.

Unit 5: Application of fossils in Stratigraphy

Biozones, index fossils, correlation.

Role of fossils in sequence stratigraphy.

Fossils and paleoenvironmental analysis.

Fossils and paleobiogeography, biogeographic provinces, dispersals and barriers.

Paleoecology – fossils as a window to the evolution of ecosystems.

Macro Palaeontology

(Full Marks – 50)

Study of morphological characters of following invertebrates: Coral, Bivalves, Gastropods, Cephalopods, Brachiopods, Trilobite, Echinoid (Identification at generic level).

Morphological studies of spores and pollens.

Elementary exercise on functional morphology of bivalves.

Basic morphometric measurements of selected invertebrate fossils (e.g., gastropods, bivalves).

Size-frequency analysis and plotting histograms of fossil size classes. Calculation of diversity indices using fossil assemblages.

Reference Books

- Agashe, S.N. (1995) *Paleobotany*. New Delhi: Oxford & IBH.
- Arnold, C.A. (1947) *An Introduction to Palaeobotany*. New York: McGraw Hill.

- Benton, Michael J. and Harper, David A. T. 2009. Introduction to Palaeobiology and the Fossil Record. Wiley-Blackwell, John Wiley & Sons, Ltd.
- Black, R.M. (1989) *The Elements of Palaeontology*. Cambridge: Cambridge University Press.
- Babin, C. (1980) *Elements of Palaeontology*. New York: John Wiley & Sons.
- Brenchley, P.J. and Harper, D.A.T. (1998) *Palaeoecology: Ecosystems, Environments and Evolution*. London: Chapman and Hall.
- Clarkson, E. N. K. (2012) Invertebrate paleontology and evolution 4th Edition by Blackwell Publishing.
- Cowen, R. (2000) *History of Life*. Oxford: Blackwell Science.
- Dasgupta, A. (2005) *An Introduction to Palaeontology*. 1st edn. Kolkata: World Press.
- Davies, M. (2008) *An Introduction to Palaeontology*. New Delhi: Read Books.
- Doyle, P. (2014) *Understanding Fossils: An Introduction to Invertebrate Palaeontology*. Hoboken, NJ: John Wiley & Sons.
- Enay, R. (2012) *Palaeontology of Invertebrates*. Berlin: Springer-Verlag.
- Foote, M. and Miller, A.I. (2006) *Principles of Paleontology*. 3rd edn. New York: W.H. Freeman and Company.
- Goldring, Roland (2014) Field Palaeontology, Routledge.
- Jackson, P.W. (2019) *Introducing Palaeontology: A Guide to Ancient Life*. Edinburgh: Dunedin Academic Press Ltd.
- Jain, P.C. and Anantharaman, M.S. (1996) *Palaeontology: Evolution & Animal Distribution*. Jalandhar: Vishal Publishing.
- Jain, S. (2017) *Fundamentals of Invertebrate Palaeontology: Macrofossils*. New Delhi: Springer India.
- Milsom, C. and Rigby S. (2010). Fossils at a Glance. Wiley-Blackwell. (Second Edition).
- Moore, R.C., Lalicker, C.G., Fischer, A.G, (2004) Invertebrate fossils. McGraw, Hill, Book Co.
- Nield, E.W. and Tucker, V.C.T. (1985) *Palaeontology – An Introduction*. Oxford: Pergamon Press.
- Prothero, D.R. (1998) *Bringing Fossils to Life: An Introduction to Palaeobiology*. New York: McGraw Hill.
- Rastogi, V.B. (1988) *Organic Evolution*. Meerut: Kedar Nath and Ram Nath.
- Raup, D.M. and Stanley, S.M. (1978) *Principles of Palaeontology*. New Delhi: CBS Publishers.
- Ray, A.K. (2008) *Fossils in Earth Sciences*. New Delhi: Prentice-Hall of India Pvt. Ltd.
- Shah, S.K. (2013). Elements of Palaeontology. Text-book Series in Geological Sciences for Graduate Students, Geological Society of India.
- Shrock, R.R. & Twenhoffel, W.H. (2002). Principles of Invertebrate Paleontology. CBS Publ.
- Shukla, A. C., & Misra, S. P. (1975). Essentials of paleobotany. Vikas Publisher.
- Stewart, W.N. and Rothwell, G.W. (2005) *Palaeobotany and the Evolution of Plants*. 2nd edn. Cambridge: Cambridge University Press.
- Willis, K.J. &McElwain, J.C. 2002. The evolution of plants. Oxford University Press

o Woods H. (1982). Paleontology Invertebrate. CBS Publications and distributors.

Geotectonics and Geomorphology

(Full Marks – 75)

Group – A: Geotectonics

(Full marks: 40)

Unit 1: Introduction to Physiographic Divisions of Earth

Crustal types: oceanic, transitional and continental crusts.

Islands, mountains belts and continental margins, ocean basins

Shield, platforms, and cratons.

Concepts of orogens.

Unit 2: Historical Perspectives

Wegener's Continental drift hypothesis and its evidences. Continental position in the past.

Sea-floor spreading hypothesis and its evidences. Magnetic time scale. Palaeomagnetism. Vine-Mathews' hypothesis. Polar-wandering. Wilson cycle.

Unit 3: Plate Tectonic Theory

Plates: physical character of plates. Distribution of plates in the Earth; macro and micro plates. Plate boundaries: types, character, Identification of boundaries. Motion along plate boundaries. Triple points. Kinematics of plate motion. Rate of plate motion. Volcanic arcs, island arcs, trenches, accretionary prisms, oceanic ridges, transform faults, aulacogens, ophiolites.

Driving mechanisms of plates.

Unit 4: Plate Tectonic Explanation of Major Physiographic Features of Earth

Alpine-Himalayan chain, Andes mountains, Japan Arc, Mid-Atlantic Ridge, African Rift, Narmada Graben, San Andreas Fault.

Unit 5: Plate Tectonics: Past and Present

Supercontinents and their breakup and assembly. Assembly and breakup of Pangaea. Other supercontinents.

Group – B: Geomorphology

(Full marks: 35)

Unit 1: Introduction to geomorphology; relationship between the landforms and the properties of earth material and different kind of processes. Endogenic and exogenic processes.

Unit 2: Geoid, topography, hypsometry, major morphological features of the earth surface. Large scale topography - plate tectonics overview, large scale mountain ranges (with emphasis on Himalayas). Tectonic geomorphology – neotectonics, active tectonics.

Unit 3: Surficial processes and geomorphology; weathering and associated landforms. Karst topography.

Landforms produced by glacial, periglacial processes, fluvial processes, aeolian processes, coastal processes.

Landforms associated with igneous activities.

Unit 4: Endogenic-exogenic interactions; rates of uplift and denudation; tectonics and drainage development; sea-level change; long-term landscape development.

Landform dating techniques – Thermoluminiscence, Optically Stimulated Luminescence, Varve counting, Fission Track dating.

Paleogeomorphology – Concept, methods, and importance.

Field Studies – 3

(Full Marks – 25)

7-day fieldwork related to mine visit (iron ore/base metal/coal). Local surface geology and hydrogeology.

Fieldwork may be carried out in and around following areas.

Ore deposits of Rajasthan; Gondwana coal fields; iron, copper and uranium ores of Singhbhum region; Manganese deposits of Central India; Iron ore deposits of Odisha.

Evaluation will be based on field performance, field notebook records, report writing, and a viva-voce examination.

Reference Books

- Allen, P.A., 1997. *Earth Surface Processes,* Blackwell publishing.
- Anderson, Robert S., and Suzanne P. Anderson. Geomorphology: the mechanics and chemistry of landscapes. Cambridge University Press, 2010.
- Van der Pluijm, Ben A., and Stephen Marshak. "Earth structure: an introduction to structural geology and tectonics." (No Title) (2004).
- Bloom, A.L., 1998. *Geomorphology: A Systematic Analysis of Late Cenozoic Landforms,* Pearson Education.
- Bridge, J.S. and Demicco, R.V., 2008. *Earth Surface Processes, Landforms and Sediment Deposits,* Cambridge University Press.
- Condie, K.C. 2016, Earth as an Evolving Planetary System. Elsevier, Amsterdam. ISBN: 978-0-12-803689-1
- Condie K.C. 2013, Plate Tectonics & Crustal Evolution
- Duff, P. M. D., & Duff, D. (Eds.). 1993. Holmes' principles of physical geology. Taylor & Francis.
- Esterbrook, D.J., 1992. *Surface Processes and Landforms,* MacMillan Publ.
- Kale, V.S. and Gupta A 2001 *1ntoduction to Geomorphology,* Orient Longman Ltd.
- Huggett, R.J. (2016) Fundamentals of Geomorphology by Taylor and Francis.
- Keary, P. and Vine, F.J., 1997. Global Tectonics. Blackwell and crustal evolution. Butterworth-Heinemann.
- Leeder, M. and Perez-Arlucea M 2005 Physical processes in earth and environmental sciences, Blackwell publishing.
- Moores, E and Twiss. R.J., 1995. Tectonics. Freeman.
- Patwardhan, A. M., 1999. The Dynamic Earth System. Prentice Hall.
- Summerfied, M.A., 2000. Geomorphology and Global tectonic. Springer Verlag.
- Thornbury, W.D. 2002. Principles of Geomorphology. CBS Publ. New Delhi.
- Valdia, K.S., 1988. Dynamic Himalaya. Universities Press, Hyderabad.
- Burbank, Douglas W., and Robert S. Anderson. "Tectonic geomorphology." (2013): 198-200.

- Walker, Mike. Quaternary dating methods. John Wiley & Sons, 2005.

Principles of Stratigraphy & Stratigraphy of India

(Full Marks – 75)

Group –A: Principles of Stratigraphy

(Full Marks – 25)

Unit 1: *Preliminary Ideas of Stratigraphic Units*: Litho-, bio- and chrono-stratigraphic units, stratotypes. Stratigraphic correlation.

Introductory concepts of chemostratigraphy, seismic stratigraphy and magnetostratigraphy Concept of chronostratigraphic vs. geochronologic units; major boundaries in the Phanerozoic.

Unit 2: *Code of stratigraphic nomenclature*: International Stratigraphic Code – development of a standardized stratigraphic nomenclature. Concepts of Stratotypes. Global Stratotype Section and Point (GSSP).

Unit 3: Facies concept in stratigraphy, Walther's Law of Facies.

Unit 4: *Paleogeography*: Concept of paleogeographic reconstruction.

Group –B: Stratigraphy of India

(Full Marks – 50)

Unit 1: Physiographic and tectonic subdivisions of India

Brief introduction to the physiographic and tectonic subdivisions of India.

Unit 2: Precambrian Stratigraphy of India

Introduction to Indian Shield. Concept of Archean nuclei of India.

Geology of Archaean Cratons: Dharwar and Singhbhum, Aravalli, Bastar.

Geology of Mobile Belts: Araballi-Delhi, Eastern Ghats, Pandean Mobile Belt, CITZ (with Satpura & Chhotanagpur). Indian Proterozoic mobile belts in supercontinent assemblies (Columbia, Rodinia, Gondwana).

Geology of Platformal Sequence: Vindhyan, Cuddapah and Chattishgarh

Unit 3: Phanerozoic Stratigraphy of India

Palaeozoic Succession of Kashmir and its correlatives from Spiti Stratigraphy.

Stratigraphy of Gondwana basins.

Triassic successions of Spiti, Jurassic of Kutch, Cretaceous successions of Cauvery basins.

Cenozoic stratigraphy of India: Kutch basin, Siwalik successions, Assam and Andaman basins and Bengal Basin.

Unit 4: Volcanic provinces of India

Deccan, Rajmahal, Sylhet Trap.

Unit 5: Stratigraphic boundaries

Important Stratigraphic boundaries in India: Precambrian-Cambrian boundary, Permian-Triassic boundary, Cretaceous-Paleogene boundary.

Reference Books

- Boggs, S. Jr. (2016). *Principles of Sedimentology and Stratigraphy*. 5th ed. Pearson Education, Boston.
- Doyle, P. & Bennett, M.R. (1996). *Unlocking the Stratigraphic Record*. John Wiley & Sons, Chichester.
- Dunbar, C.O. & Rodgers, J. (1961). *Principles of Stratigraphy*. John Wiley & Sons, New York.
- Khare, N. (ed.), 2021. *Quaternary Climate Change over the Indian Subcontinent*. CRC Press / Taylor & Francis, Boca Raton.
- Korisettar, R., Wadia, S. W. & Kale, V. S. (eds), 1995. *Quaternary Environments and Geoarchaeology of India*. Memoir M-32. Geological Society of India, Bangalore.
- Krishnan, M. S. (1982) Geology of India and Burma, CBS Publishers, Delhi
- Kumar R. (2010). *Fundamentals of Historical Geology and Stratigraphy of India*. 2nd ed. New Age International Publishers, New Delhi.
- Naqvi, S.M. (2005). *Geology and Evolution of the Indian Plate: From Hadean to Holocene (4 Ga to 4 Ka)*. Capital Publishing Company, New Delhi.
- Pascoe, E.H. (1968). *A Manual of the Geology of India and Burma*. 3rd ed. Government of India Press, Delhi.
- Ramakrishnan, M. & Vaidyanadhan, R. (2008) Geology of India Volumes 1 & 2, Geological society of India, Bangalore.
- Valdiya, K. S. (2010) The making of India, Macmillan India Pvt. Ltd.
- Lemon, R.L. (1990) Principles of Stratigraphy, Meril Publishing.
- Mathur, U. B., 2005. Quaternary Geology: Indian Perspective. Memoir M-63. Geological Society of India, Bangalore.
- Narayana, A. C. (ed.) (2002) Late Quaternary Geology of India and Sea Level Changes. Memoir No. 49, Geological Society of India, Bangalore.
- Ravindra Kumar (1985) Fundamentals of Historical Geology and Stratigraphy of India, John Wiley.
- Schoch, R.M. (1989). *Stratigraphy: Principles and Methods*. Van Nostrand Reinhold, New York.
- Tiwari, N., Singh, V. & Mehra, S. B. (eds), (2023) *Quaternary Geoarchaeology of India*. Geological Society London Special Publication 515. Geological Society, London.
- Valdiya, K.S. (2010). *The Making of India: Geodynamic Evolution*. Macmillan India, New Delhi.
- Wadia, D.N. (1973). *Geology of India*. 4th ed. McGraw–Hill, New Delhi.

Fuel Geology

(Full Marks – 50)

Unit 1: Coal

Definition and origin of Coal; Condition of formation of coal.

Basic classification of coal: ASTM and Indian classification.

Fundamentals of Coal Petrology - Introduction to lithotypes, microlithotypes and macerals in coal.

Proximate and Ultimate analysis, optical properties of coal.

Correlation of coal seams. Industrial utilization of coal. Coal resources of India. Estimation and categorization of coal resources.

Coal Bed Methane (CBM): global and Indian scenario.

Unit 2: Petroleum

Chemical composition and physical properties of crudes in nature.

Origin of petroleum.

Reservoir rocks: general attributes.

Classification of reservoir rocks - clastic and chemical.

Hydrocarbon traps: definition, anticlinal theory and trap theory.

Classification of hydrocarbon traps - structural, stratigraphic and combination.

Time of trap formation and time of hydrocarbon accumulation.

Cap rocks - definition and general properties.

Well logging.

Petroliferous basins of India.

Unit 3: Nuclear Fuel

Geochemistry of U and Th, geochemical abundance of radioactivity in crustal rocks, important minerals, types of U and Th deposits, nuclear raw material resources of India, usage of nuclear energy.

Unit 4: Unconventional Energy Resource

Gas Hydrate and Geothermal Energy.

Potential renewable energy sources: Solar, OTEC, wind, wave and tidal.

Fuel Geology and Reserve Estimation

(Full Marks – 50)

Study of hand specimens of coal.

Reserve estimation based on geometrical models (square, rectangular, triangular and polygon blocks). Reserve estimation of coal.

Codification of Indian coal.

Petroleum exploration using seismic section interpretation. Interpretation of well-logs and VSP data. Calculation of formation-pressures. Estimation of oil and gas reserves.

Reference Books

- Bastia, R., & Radhakrishna, M. (2012). Basin evolution and petroleum prospectivity of the continental margins of India (Vol. 59). Newnes.
- Boyle, R.W., 1982: Geochemical Prospecting for Thorium and Uranium Deposits-Elsevier
- Chandra D. (2007). Chandra's Textbook on applied coal petrology. Jijnasa Publishing House.
- Chandra, D., Singh, R.M. and Singh, M.P. (2000) Textbook of Coal (Indian Context)-Tara Book Agency, Varanasi.

- Dahlkamp, F.J., 1993: Uranium Ore Depostis-Springer Verlag
- Durrance, E.M., 1986: Radioactivity in Geology. Principles and Application-Ellis Hoorwool
- Holson, G.D. and Tiratsoo, E.N., 1985: Introduction to Petroleum Geology-Gulf Publ. Houston, Texas
- Nath, Manabendra. Fuel Geology - *Vishal Publishing Co.*
- Levorsen, A.I. 2004.Geology of petroleum. American Association of Petroleum Geologists. CBS Publishers and Distributors.
- Selly R. C. (2014). Elements of Petroleum geology: Third Edition, Academic Press
- Singh, M.P., (Ed.), 1998: Coal and Organic Petrology-Hindustan Publ. Corp., New Delhi
- Tissot, B.P. and Welte, D.H., 1984: Petroleum Formation and Occurrence-Springer Verlag
- Max, Michael D., Arthur H. Johnson, and William P. Dillon. Economic geology of natural gas hydrate. Dordrecht: Springer Netherlands, 2006.
- Stober, Ingrid, and Kurt Bucher. "Geothermal energy." Germany: Springer-Verlag Berlin Heidelberg. doi 10 (2013): 978-3.

Hydrogeology

(Full Marks – 50)

1. Introduction to hydrogeology; scope and socio-economic relevance.
2. Hydrologic cycle – Definition and scope, components of hydrologic cycle: precipitation, evapotranspiration, run-off, percolation, infiltration.
3. Distribution and classification of sub-surface water; definition of groundwater. Water table and piezometric/potentiometric surface. Classification of water bearing formations.
4. Hydrological properties of aquifers: porosity, void ratio, permeability, specific yield, specific retention, storage coefficient, hydraulic conductivity, transmissivity, hydraulic diffusivity, groundwater velocity, Isotropy and Anisotropy, Homogeneity and Heterogeneity.
5. Theory of groundwater flow: Groundwater flow and solute transport –laminar flow, turbulent flow; groundwater energy and hydraulic head; Darcy's law and its applications and validity, Reynold's number. Flow lines and equipotential lines, drawing groundwater contours from depth to water table.
6. Groundwater recharge and discharge, surface water – groundwater interaction, influent and effluent streams, base-flow (basic ideas). Concepts of water balance studies.
7. Geologic factors governing groundwater occurrence and movement. Sea water ingression. Groundwater level fluctuations and environmental influences; Impact of climate change on groundwater
8. Groundwater quality: Physical and Chemical parameters of groundwater, Pollution indicators, Water Quality Interpretation; Water Quality Standards; Water Facies Diagrams Groundwater Exploration: Geophysical methods

9. Introduction to hydrogeology; scope and socio-economic relevance.
10. Hydrologic cycle – Definition and scope, components of hydrologic cycle: precipitation, evapotranspiration, run-off, percolation, infiltration.
11. Distribution and classification of sub-surface water; definition of groundwater. Water table and piezometric/potentiometric surface. Classification of water bearing formations.
12. Hydrological properties of aquifers: porosity, void ratio, permeability, specific yield, specific retention, storage coefficient, hydraulic conductivity, transmissivity, hydraulic diffusivity, groundwater velocity, Isotropy and Anisotropy, Homogeneity and Heterogeneity.
13. Theory of groundwater flow: Groundwater flow and solute transport –laminar flow, turbulent flow; groundwater energy and hydraulic head; Darcy's law and its applications and validity, Reynold's number. Flow lines and equipotential lines, drawing groundwater contours from depth to water table.
14. Groundwater recharge and discharge, surface water – groundwater interaction, influent and effluent streams, base-flow (basic ideas). Concepts of water balance studies.
15. Geologic factors governing groundwater occurrence and movement. Sea water ingression. Groundwater level fluctuations and environmental influences; Impact of climate change on groundwater
16. Groundwater quality: Physical and Chemical parameters of groundwater, Pollution indicators, Water Quality Interpretation; Water Quality Standards; Water Facies Diagrams Groundwater Exploration: Geophysical methods
17. Hydrostratigraphic units; Groundwater provinces of India. Groundwater Budget; Groundwater resources of India – its future.
18. Groundwater Exploitation and Management; Conjunctive use; Rainwater harvesting and artificial recharge of groundwater.
19. Hydrostratigraphic units; Groundwater provinces of India. Groundwater Budget; Groundwater resources of India – its future.
20. Groundwater Exploitation and Management; Conjunctive use; Rainwater harvesting and artificial recharge of groundwater.

Hydrogeology Practical

(Full Marks – 50)

1. Water potential zones of India (map study).
2. Simple numerical problems related to determination of porosity, void ratio, saturation percentage, bulk density, water content.
3. Calculation of Effective Porosity, Groundwater Velocity and Travel Time.
4. Simple numerical problems related to determination of Permeability in field and laboratory.

5. Numerical problems on Groundwater storage in terms of Specific Yield and Specific Retention.
6. Graphical representation of chemical quality data in Piper diagram.

Reference Books

- Davie, Tim. 2008, Fundamentals of Hydrology. 2nd Ed. Routledge.
- Davis, S. N. and De Weist, R.J.M. 1966. Hydrogeology, John Wiley & Sons Inc., N.Y.
- Fetter, C.W., 2014, Applied Hydrogeology, Pearson Education Limited, Fourth edition.
- H. M. Raghunath., H. M. (2006) Hydrology: Principles, Analysis, and Design by New Age International Publishers, 2006, Revised Second edition.
- Hiscock, Kevin M. and Bense, Victor F. 2014, Hydrogeology: Principles and Practice, 2nd Ed., Wiley Blackwell.
- Introduction to Hydrology by Warren Viessman Jr. and Gary Lewis. Printice Hall, 2003, Fifth edition.
- Karanth K.R., 1987, Groundwater: Assessment, Development and management, Tata McGraw-Hill Pub. Co. Ltd
- Raghunath, H. M., 1990. Groundwater. Wiley Eastern Ltd.
- Sharp, John M. Jr. 2007. A Glossary of Hydrogeological Terms by Department of Geological Sciences, The University of Texas.
- Singhal B. B. S. and Gupta R. K., 2010, Applied hydrogeology of fractured rocks.
- Subramaniam, V., 2000. Water-Kingston Publ. London.
- Todd, D. K. 1980. Groundwater hydrology, 2nd Ed., John Wiley & Sons, N.Y.
- Zektser, Igor S. and Everett, Lorne G. (Editors). 2004. Groundwater Resources of the World and Their Use, UNESCO.

Structural Geology – 2

(Full Marks – 50)

Unit 1. Stress:

Concept of stress, normal stress, shear stress, principal axes of stress, planes of maximum shear stress. 2D and 3D stress. Stress ellipsoid. Mohr circle of stress.

Unit 2. Strain:

Displacement and strain, longitudinal and shear strain, principal axes of strain, homogeneous and inhomogeneous strain, rotational and irrotational strain, pure shear and simple shear, strain ellipse and strain ellipsoid. Vorticity.

Technique of strain measurement in 2D – Fry & Wellman's method, R_f-φ, Mohr diagram.

Unit 3. Fracturing and Faulting of rocks:

Brittle deformation mechanisms, three types of fracture.

Failure and fracture criteria, Tensile, Mohr-Coulomb envelope, von Mises envelope, Griffith's model.

Anderson's classification of faults. Fault formation in non-porous and porous rocks. Fault growth and seismicity.

Unit 4. Rheology

Factors controlling deformation behaviour of rocks – confining pressure, temperature, time, solution. Brittle and ductile deformation. Creep of rocks, intracrystalline plastic deformation. Creep laws – Nabarro–Herring creep; Coble creep, dislocation creep.

Unit 5. Folding Mechanism:

Concepts orthogonal flexure, flexural slip and flexural flow, passive shear. Buckling, bending and volume loss folding, geometrical characteristics of the folds formed by these three mechanisms. Fault-related folding.

Unit 6. Superposed Deformation:

Basic concepts of superposed deformation for passive shear folds and buckle folds. Interference patterns in superposed folding, deformation of older planar and linear structures, geometry of new structures.

Unit 7. Shear zone:

Basic concepts, shear zone rocks, common mesoscopic and microscopic structures in shear zones; origin of sheath/eye fold; subsidiary fault and fracture geometries, shear sense indicators. Strain model of shear zone.

Unit 8. Fold and thrust belt:

Brief descriptions of thrust system, thrust sheet, leading and trailing edges of thrust sheet, forelimb and backlimb. Emergent thrusts, blind thrusts, window and klippe, geometry of thrusts, flats and ramps, cutoff.

Definition of fold-thrust belts, detachment fault or décollement, imbricate structure or imbricate fan, duplex structure, forethrust and backthrust. Basic ideas on tectonic setting of fold-thrust belts.

Study of Geological Maps and Completion of Outcrops

(Full Marks – 50)

Simple pole rotation problems using stereograms.

Interpretation of simple geological maps showing unconformities, folded and faulted strata.

Completion of outcrops of homoclinal strata and unconformities on horizontal and uneven topography. Completion of outcrops of folded and faulted strata on horizontal topography.

Strain analysis (Fry method).

Reference Books

- Billings, M. P. (1987). Structural Geology, 4th edition. Prentice-Hall.
- Davis, G. H., Reynolds, S. J., and Kluth, C. F. (2012). Structural Geology of Rocks and Region. 3rd Edition. John Wiley & Sons, Inc.
- Fossen, H. (2016). Structural Geology. Second Edition. Cambridge University Press.
- Lisle, R. J. and Leyshon, P. R. (2004) Stereographic projection techniques for structural geologists and civil engineers. Second Edition. Cambridge University Press.
- Marshak, S. and Mitra, G. (1988). Basic Methods in Structural Geology. Prentice Hall.
- Phillips, F. C. (1973). The use of stereographic projection in structural geology. Hodder.

- Ragan, D. M. (2009). Structural Geology: an introduction to geometrical techniques (4th Ed). Cambridge University Press (For Practical)
- Twiss, R. J. and Moores, E. M. (2007) Structural Geology. Second Edition. W. H. Freeman and Company.

Remote Sensing and GIS

(Full Marks – 50)

Unit 1: Basic Concepts of Remote Sensing

Definition and development of Remote Sensing; its advantages and limitations; Properties of electromagnetic waves; electromagnetic spectrum, atmospheric window, interaction of EM wave with target, specular and Lambertian reflector, Types of scattering – Mie scattering, Rayleigh scattering etc. Spectral Signature curve of different objects, passive and active RS systems, types of RS; thermal remote sensing & microwave remote sensing.

Unit 2: Photogeology

Types and acquisition of aerial photographs; scale and resolution; principles of stereoscopy, relief displacement, vertical exaggeration, and distortion. Elements of air photo interpretation.

Unit 3: Optical Remote Sensing

Satellite Remote Sensing – orbits, platform, scanners (along-track and across-track), optical mechanical scanners, CCD linear arrays, CMOS, sensor characteristics – resolution (spatial, spectral, radiometric, temporal), types of satellite data (panchromatic, multi=spectral and hyperspectral data), DEM analysis. Indian space program from IRS-1A (1962) till date.

Unit 4. Digital Image Processing:

Digital image rectification and restoration techniques; radiometric and geometric correction; Image enhancement techniques – image histogram, contrast manipulation, edge enhancement. Multispectral image analysis; Band ratio, classification method- supervised & un-supervised.

Unit 5: GPS & GIS:

Datum, concepts of GPS, components of GPS, factors affecting GPS accuracy, DGPS, Indian Regional Navigation Satellite System (IRNSS), Integrating GPS data with GIS, Projection and Co-ordinate systems. Definition & Elements of GIS, types of GIS data (Raster & Vector), attribute data, geodatabase, Application of GIS in Earth Science.

Application of RS and GIS in Geology

(Full Marks – 50)

Unit 1: Aerial photo interpretation

Study of aerial photographs with common rock types – granites, mafic rocks, sandstones, claystones/shales.

Study of large-scale structures (dykes, faults, folds) from aerial photographs.

Various aeolian, glacial, fluvial and marine landforms in aerial photographs.

Unit 2: Image interpretation.

Interpretation of single band/PAN satellite images including border/annotation lines information (metadata). Interpretation of MSS and FCC images; visual and digital interpretation of digital images.

Unit 3: GIS Application.

Georeferencing of toposheet/satellite imagery; creation of vector data (point, line and polygon), adding an attribute, spatial analysis, Map generation using open source GIS software, Analysis and interpretation of satellite data in different band combination.

Reference Books

- Bhatta, B., 2008. Remote Sensing and GIS. Oxford, New Delhi.
- Demers, M.N., 1997. Fundamentals of Geographic Information System, John Wiley & sons. Inc. Hoffmann-Wellenhof, B., Lichtenegger, H. and Collins, J., 2001. GPS: Theory & Practice, Springer Wien New York.
- Gupta, R.P., 1990. Remote Sensing Geology. Springer Verlag.
- Jensen, J.R., 1996. Introductory Digital Image Processing: A Remote Sensing Perspective, Springer- Verlag.
- Joseph, George 2018, Fundamentals of Remote Sensing, The Orient Blackswan.
- Lillesand, T. M. & Kiefer, R.W., 2007. Remote Sensing and Image Interpretation, Wiley. Richards, J.A. and Jia, X., 1999. Remote Sensing Digital Image Analysis, Springer-Verlag.
- Moffitt, F.H. and Mikhail, E.M., 1980 Photogrammetry-Harper and Row
- Millor, V.C., 1961 Photogeology. Mc Graw Hill
- Pandey, S.N., 1987. Principles and Application of Photogeology. Wiley Eastern, New Delhi.
- Rampal K.K. 1999. Hand book of aerial photography and interpretation. Concept publication.
- Sabins, F.F., 1985. Remote Sensing – Principles and Applications. Freeman.
- Siegal, B.S. and Gillespie, A.R., 1980. Remote Sensing in Geology. John Wiley.
- www.isro.org, and www.nrsc.gov.in

Recommended Software:

- *Desktop:* Use *QGIS* + *GRASS* / *SAGA* for lab exercises (remote sensing & analysis).
- *Android*: Encourage *QField* and *Input App* for field mapping projects (they sync with QGIS).

Engineering Geology

(Full Marks – 50)

Unit 1: Introduction: Role of engineering geologists in planning, design and construction of major man-made structural features.

Site investigation and characterization.

Unit 2: Slope stability and mass wasting; Types of block failure, factor of safety, landslide classification.

Unit 3: Foundation: Types of foundations. Foundation treatment: Grouting, Rock Bolting and other support mechanisms.

Unit 4: Mechanical properties of rocks - Strength (Compressive, Tensile, Shear), Various moduli and Stress-Strain responses of rocks.

Stress Strain Models: Constitutive relationships - Elastic, Elasto-plastic, Visco-elastic, Visco-plastic and Elasto-viscoplastic.

Physical properties of rocks: Porosity, Density, Moisture content, Degree of saturation, Coefficient of permeability.

Unit 5: Engineering Classification of Rocks: Classification of intact rocks, Rock mass classifications - Rock Quality Designation (RQD), Rock Structure Rating (RSR), Rock Mass Rating (RMR), Norwegian Geotechnical Classification (Q-system).

Unit 6: Engineering structure of Dams and their classification based on geometry and uses.

Geological, Geotechnical and Environmental considerations for dams and reservoirs.

Dam collapse, dam induced earthquakes and mitigation measures.

Unit 7: Engineering structures of Tunnels & Bridges and their classification based on geometry and uses.

Tunnels and Tunnelling methods: geological considerations for tunnel alignment; soft ground tunnelling and hard rock tunnelling methods.

Engineering Geology Practical

(Full Marks – 50)

Computation of reservoir area, catchment area, reservoir capacity and reservoir life.

Computation of RQD by direct and indirect methods; RSR (based on case history).

Analysis of discontinuities in rocks for estimating stability of surface - Stereonet analysis for slope stability; identifying modes of failure by stereonet analysis (Markland Test).

Stability of mass: Mohr diagram construction for rock failure and potential slip planes.

Reference Books

- Bell, F.G. (2007). Engineering Geology. Butterworth-Heineman.
- Blyth, F.G.H. and M. H. de Freitas (1984) Geology for Engineers, Butterworth- Heinemann Title
- Gokhale, K.V.G. (2006) Principles of engineering geology, BS publications.
- Goodman, R.E. (1993). Engineering Geology: Rock in Engineering constructions. John Wiley and Sons, New York.
- Johnson, R.B. and De Graf, J.V. (1988). Principles of Engineering Geology, John Wiley.
- Keshvallu, Chenna (2018) Text book of Engineering Geology, Laxmi Publications.
- Krynin, D.P. and Judd W.R. (1957). Principles of Engineering Geology and Geotechnique. McGraw Hill (CBS Publ.).
- Pradhan S.P., Vishal V., Singh T.N. (2019) Landslides: Theory, Practice and Modelling, Springer.

- Ries, H. and T. L. Watson, (1949) Elements of Engineering Geology, New York, John Wiley & Sons, Inc.
- Schroeder, W.L., Dickenson, S.E., Warrington, D.C. (1984)-Soils in construction-John Wiley and Sons.
- Singh, B and Goel, R.K. (2011)-Engineering Rock Mass Classification: Tunneling, Foundations, and Landslides-Elsevier.
- Waltham, T. (2009). Foundations of Engineering Geology (3rd Edn.). Taylor and Francis.
- Wyllie, D.C., & Mah, C. (2004). Rock Slope Engineering: Fourth Edition (4th ed.). CRC Press.
- Wyllie, Duncan C. (2018)-Rock Slope Engineering: Civil Applications-CRC Press, Taylor and Francis Group.

Summer Internship: Earth Science

(Full Marks – 75)

Each student must undergo a **compulsory training program of at least one week's duration** in a reputed industry, corporate house, laboratory, or external academic institute engaged in geological, geophysical, geochemical, or other Earth Science–related field-based and/or academic activities.

*At the end of the training, students are required to prepare and submit a **comprehensive report** along with a **Completion Certificate.***

Evaluation will be based on performance, notebook records, report writing, and a viva-voce examination.

Exploration Geology

(Full Marks – 50)

Unit 1: Mineral Resources

Resource reserve definitions, Mineral resources in industries – historical perspective and present.

A brief overview of classification of mineral deposits with respect to processes of formation in relation to exploration strategies.

Unit 2: Prospecting and Exploration

Principles of mineral exploration.

Prospecting and exploration- conceptualization, methodology and stages.

Sampling, subsurface sampling including pitting, trenching and drilling. Geochemical exploration.

Geophysical methods of exploration: Resistivity, gravity, seismic and magnetic methods.

Unit 3: Evaluation of data

Evaluation of sampling data.

Mean, mode, median, standard deviation and variance.

Unit 4: Drilling and Logging

Core and non-core drilling.

Planning of bore holes and location of boreholes; on ground Core-logging.

Introduction to drilling technology: percussion, diamond, reverse circulation, air core, wireline, BH deviation survey.

Unit 5: Reserve estimations and Errors

Principles of reserve estimation, density and bulk density.

Factors affecting reliability of reserve estimation.

Reserve estimation based on geometrical models of uneven ore bodies. Regular and irregular grid patterns, statistics and error estimation.

Reserve estimation: cutoff, ROM, cross section, lo core, bulk/muck/grab/car/stack ng section, level plan and inverse distance; classification of reserves/resources (conventional, USGS, UNFC, and JORC).

Exploration Geology Practical

(Full Marks – 50)

- Identification of anomaly.
- Concept of weighted average in anomaly detection Geological cross-section.
- Models of reserve estimation.
- Assaying process, ore reserve estimation from surface and sub-surface bodies, and evaluation techniques for determining the grade, tonnage, and economic viability of ore deposits.

Reference Books

- Arogyaswamy, R.P.N. (1996) *Courses in Mining Geology*. 4th edn. New Delhi: Oxford & IBH Publishing.
- Banerjee, P.K. and Ghosh, S. (1997) *Elements of Prospecting for Non-Fuel Mineral Deposits*. Chennai: Allied Publishers.
- Clark, G.B. (1967) *Elements of Mining*. 3rd edn. New York: John Wiley & Sons.
- Dobrin, M.B. and Savit, C.H. (2003) *Introduction to Geophysical Prospecting*. Reprint edn. New York: McGraw-Hill.
- Haldar, S.K. (2013) *Mineral Exploration: Principles and Applications*. Amsterdam: Elsevier.
- Kearey, P., Brooks, M. and Hill, I. (2002) *An Introduction to Geophysical Exploration*. 3rd edn. Oxford: Blackwell Science.
- Marjoribanks, R.W. (1997) *Geological Methods in Mineral Exploration and Mining*. London: Chapman & Hall.
- Moon, C.J., Whateley, M.K.G. and Evans, A.M. (2006) *Introduction to Mineral Exploration*. New Delhi: Wiley-Blackwell.
- Rajendran, S., Ramakrishna, T.S. and Geological Society of India (2007) *Mineral Exploration: Recent Strategies*. Bangalore: Geological Society of India, Memoir 62.
- Telford, W.M., Geldart, L.P. and Sheriff, R.E. (1990) *Applied Geophysics*. Cambridge: Cambridge University Press.

- Wyllie, D.C. and Mah, C. (2004) *Rock Slope Engineering: Fourth Edition*. Boca Raton: CRC Press.

Geophysics

(Full Marks – 50)

Unit 1: Geology and Geophysics

Interrelationship between geology and geophysics, Role of geological and geophysical data in explaining geodynamical features of the earth.

Unit 2: General and Exploration geophysics

Basic principles of Geophysics. Different types of geophysical methods - gravity, magnetic, electrical and seismic; their principles and applications.

Unit 3: Geophysical Methods

Gravity methods: introduction, Gravity potential and field due to different simple bodies and structures. Field procedure. Bouguer gravity anomalies, interpretations & field-cases.

Magnetic methods: introduction, magnetic properties of rocks, geomagnetic field, field procedure, measurement of magnetic anomalies, interpretation.

Electrical method: Introduction, self-potential, earth resistivity, different arrays, profiling & sounding techniques, interpretation & field cases. Induced polarization. Telluric & electromagnetic methods.

Seismic method: introduction, refraction methods, layered earth refraction studies, hidden layer problem, correction, instruments, field procedures, interpretation.

Basic knowledge on Geophysical Signal Processing – Concepts and Usage of corrections in geophysical data (seismic and gravity data). Filtering, noise reduction, and enhancement in geophysical data interpretation.

Ground-Penetrating Radar (GPR): its principles, data acquisition, and applications in shallow subsurface investigations,

Unit 4: Geophysical field operations

Different types of surveys, grid and route surveys, profiling and sounding techniques

Scales of survey, Presentation of geophysical data

Unit 6: Geophysical anomalies

Correction to measured quantities, geophysical, anomaly, regional and residual (local) anomalies, factors controlling anomaly, and depth of exploration.

Reference Books

- Bhimasarikaram V.L.S., 1990, Exploration Geophysics - An Outline by Association of Exploration Geophysicists, Osmania University, Hyderabad.
- Dentith M. and Mudge S. (2014) Geophysics for the Mineral Exploration Geoscientist. Cambridge University Press, New York. 438p
- Dobrin, M.B. (1984) An introduction to Geophysical Prospecting. McGraw-Hill, New Delhi.

- Keary P, Brooks M and Hill I (2002) An introduction to Geophysical Exploration (3rd ed.) Balckwell Science, Oxford. 262p.
- Lowe C., Thomas M.D., Morris W.A. (1999) Geophysics in Mineral Exploration: Fundamentals and Case Histories. Geological Association of Canada, Ontario. 175p.
- Lowrie, W. (2007). Fundamentals of geophysics. Cambridge University Press.
- Rao R., Prasaranga M.B., 1975, Outlines of Geophysical Prospecting - A manual for geologists by University of Mysore, Mysore.
- Telford, W. M., Geldart, L. P., & Sheriff, R. E. (1990). *Applied geophysics* (Vol. 1). Cambridge university press.

Numerical Application in Geology

(Full Marks – 50)

Unit 1: Numerical problems on Tectonics.

- Geometry of plate tectonics: Vector solutions for plate movements in 2D.
- Problems of plate movements - Rotations on sphere.
- Analysis of palaeomagnetic data: Palaeo pole position and APWP.

Unit 2: Numerical problems on Geomorphology.

- Preparation of longitudinal profile of a river. Calculating stream length gradient index.
- Morphometry of a drainage basin. Interpretation of geomorphic processes from the geomorphology of the area.

Unit 3: Numerical problems on Geophysics.

- Preparation and interpretation of gravity, magnetic and electrical anomaly profiles and contour maps on the basis provided data.
- Calculation of Richter magnitude from P and S wave interval data.
- Study and interpretation of seismic reflector geometry: Interpretation of underground structure on the basis of seismic data.

Environmental Geology and Marine Geology

(Full Marks – 75)

Group – A: Environmental Geology

(Full Marks – 40)

Unit 1: Definition, Concept, Scope and Importance of Environment Geology.

Unit 2: Global Environmental concerns; Environmental Treaties and Accords; Concepts of Sustainability. Concept of risk, hazards, disaster and catastrophe.

Unit 3: Basics of Environmental Geomorphology: Geomorphic Mapping and Environmental Project Planning.

Unit 4: Environmental impacts of Natural and Man-made hazards and their mitigation - Earthquake, volcanism, landslides, floods, droughts.

Unit 5: Preliminary Concepts of Environmental Pollution: Air, Noise, Land, Soil and Marine. Climate change and global warming; sea level rise.

Unit 6: Waste disposal sites: Solid, Liquid and Nuclear.

Unit 7: Renewable and Non-Renewable Resources: Eco-friendly utilization, conservation and management.

Unit 8: Principles and Methods of Environmental Impact Statement (EIS), Environmental Impact Assessment (EIA), Environmental Management Plan (EMP) including Disaster Management Plan (DMP)**,** Environmental Management; Environmental Audit.

Unit 9: Environmental Impacts of Mining, River Valley projects (dams, reservoirs) and other infrastructure development projects.

Unit 10: Risk Analyses; ISO 14000; Life Cycle Analysis (LCA).

Unit 11: Corporate Social Responsibility; Environmental Ethics, Case Studies of EIA/EMP.

Group – B: Marine Geology

(Full Marks – 35)

Unit 1: Broad Physical, Chemical, and Geological Processes of the Ocean and their environmental impacts.

Unit 2: Physiography of the Ocean Bed; Ocean Sediments.

Unit 3: Arctic Ocean and climate; Southern Ocean and climate.

Classification of the Sea Coast; Natural Disaster and Its Influence on Coastal Environment.

Unit 4: Mineral and Energy Resources of the Ocean: Poly-metallic Deposits, Gas Hydrates; Conflicts in Oceanic Resource Use.

Unit 5: Air-Sea-Land Interaction; Waves and Currents.

Unit 6: Practices in Oceanic Pollution Management - Anthropogenic Impacts and Causes of ocean degradation.

Unit 7: Sea Surface Micro-layer; Sea Surface Temperature and Impacts on Fishing Zone.

Unit 8: Brief Overview on Marine ecosystem – Its Preservation.

Unit 9: Introduction to Palaeo-oceanography.

Unit 10: Coastal Hazard Preparedness (Geo-scientific Approach); Tsunami Warning Signal; Hazard Risk Assessment. SDG – 14.

Reference Books

Group – A

- Bell, F.G., 1999: Geological Hazards-Routledge, London
- Bender, M. (2013) Paleoclimate, Princeton Premiers in Climate
- Bradley R. S., (1999), Paleoclimatology: Reconstructing climates of the quaternary. Academic Press v. 64 of International Geophysical series.
- Bryant, E., 1985: Natural Hazards-Cambridge University Press
- Keller, E.A., 1978: Environmental Geology-Bell and Howell, USA

- Patwardhan, A.M., 1999: The Dynamic Earth System-Prentice Hall
- Ruddiman, W.F. (2008) Earth's Climate, Past and Future, WH Freeman & Co. Shepherd, Submarine Geology.
- Smith, K., 1992: Environmental Hazards-Routledge, London
- Subramaniam, V., 2001: Textbook in Environmental Science-Narosa International
- Valdiya, K.S., 1987: Environmental Geology-Indian Context-Tata McGraw Hill

Group – B

- Brian, J. S., Barbara, W.M., 2010. The Blue Planet: An Introduction to Earth System Science, 3rd Edition, Wiley.
- Dronkers J. (2005) Dynamics of coastal systems, World Scientific
- Eugen Seibold (Author), Wolfgang H. Berger (Author); 1996. The Sea Floor: An Introduction to Marine Geology, Springer; 3rd ed. 1996 edition
- James P. Kennett, Marine Geology. Published November 11th 1981 by Prentice Hal
- Jon Erickson, (1996). Marine Geology: Under Landforms and Life Forms (Changing Earth S.). Facts On File Inc (25 April 1996)
- Kenneth, J. (1982) Marine Geology and Geophysics.
- Mukherjee S., Ghosh K.K., Chanda A. 2023, Environmental Oceanography and Coastal Dynamics: Current Scenario and Future Trends. Springer, 440p.
- Physical Geology Earth Revealed (Sixth Edition). 2006. Carlson-Plummer-McGeary. McGraw-Hill
- The Open University (1989) Ocean chemistry and deep sea sediments.
- Weisberg J., and Parish, H., Introductory Oceanography. McGraw Hill, 1974.
- Woodroffe, C.D. (2013) Coast: Form, process and evolution, Cambridge University Press.
- Wright J. and Colling A. (1995) Seawater: its Composition, Properties and Behaviour, The Open University

Palaeontology – 2

(Full Marks – 50)

Unit 1. Study of major micro-invertebrate groups

Study of functional morphology, biostratigraphic significance, adaptation and major steps in evolution of Foraminifera, Ostracoda. Introduction to Pteropoda, Calcareous algae, Radiolaria, Conodonts, Bryozoa and Cocolithophores.

Application of microfossils in petroleum exploration and palaeoenvironmental reconstruction.

Unit 2: Study of vertebrates

Origin of vertebrates and major steps in vertebrate evolution.

Brief accounts of Gondwana vertebrates of India with special reference to the dinosaurs.

Evolution of horse and elephant and their intercontinental migrations.

Human evolution.

Unit 3: Ichnology

Introduction ichnology. Definitions.

Ichnotaxonomy and classification.

Palaeoecology and trace fossils.

Micropaleontology, Ichnology and Study of Vertebrate Teeth

(Full Marks – 50)

Applied Micropaleontology: Morphology of major groups of micro-invertebrates; Determination of relative age and depth of deposition from larger and smaller foraminiferal fossil assemblages respectively; Elementary problems on biostratigraphy using foraminifera.

Study of morphological characteristic of vertebrate teeth: Stegodon, Rhinoceros, *Hipparion* and *Equus*.

Identification of ichnofossils: *Domichnia*, *Pascichnia*, *Repichnia*, *Fodinichnia*, *Cubichnia* and Trackways.

Problems on biostratigraphic zonation, paleoecology, and paleobiogeography based on given fossil assemblages.

Comparison of trace fossil morphotypes (viz. Tracks and trails) using numerical data.

Reference Books

- Armstrong, H.A. and Brasier, M.D. (2005) *Microfossils*. Malden, MA: Blackwell Publishing.
- Benton, M.J. (2014) *Vertebrate Palaeontology*. 4th edn. Chichester: Wiley-Blackwell.
- Bignot, G. (1985) *Elements of Micropaleontology*. Boston: IHRDC.
- Brasier, M.D. (1980) *Microfossils*. London: George Allen & Unwin.
- Boltovskoy E., Giussani G., Watanabe S., Wright R.C. (2011) Atlas of Benthic Shelf Foraminifera of the Southwest Atlantic. by Esteban Boltovskoy, Graciela Giussani, Silvia Watanabe, Ramil Wright Springer, 154p.
- Bromley, R.G. (1996) *Trace Fossils: Biology, Taphonomy and Palaeoecology*. 2nd edn. London: Chapman & Hall.
- Colbert, E.H. and Minkoff, E.C. (2001) *Evolution of Vertebrates*. Hoboken, NJ: Wiley Liss.
- Cowen, R. (2000) History of Life, Blackwell Science.
- Crimes, T.P. and Harper, J.C. (eds.) (1977) *Trace Fossils 2: Geological Journal Special Issue 9*. Liverpool: Seel House Press.
- Fastovsky, D.E. and Weishampel, D.B. (1996) *The Evolution and Extinction of the Dinosaurs*. Cambridge: Cambridge University Press.
- Haq, B.U. and Boersma, A. (1978) *Introduction to Marine Micropalaeontology*. Amsterdam: Elsevier.
- Hasiotis, S.T. (2007) *Continental Trace Fossils: An Introduction to Ichnology*. Salt Lake City: University of Utah Press.
- Haynes, J.R., 1981: Foraminifera-John Wiley
- Holbourn, Ann, Henderson Andrew S., MacLeod, Norman (2013) Atlas of Benthic Foraminifera. Wiley-Blackwell, 656p.
- Johansson, C. Z., Underwood, M. Richter, (2019) Evolution and development of Fishes, Cambridge University Press.

- Jones, R.W. (2011) *Applications of Palaeontology: Techniques and Case Studies*. Cambridge: Cambridge University Press.
- Kathal, P.K. (2012) *Application of Microfossils*. New Delhi: CBS Publishers & Distributors.
- MacEachern, J.A., Bann, K.L., Gingras, M.K. and Pemberton, S.G. (2007) 'The Ichnofacies Paradigm: A 25-Year Retrospective'. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 245(1-2), pp. 1-28.
- Martin, A.J. (2014) *Dinosaur Footprints and Trace Fossils of North America*. Bloomington, IN: Indiana University Press.
- Miller, W. (2007) *Trace Fossils: Concepts, Problems, Prospects*. Amsterdam: Elsevier.
- Romer, A.S. 2004. Vertebrate Palaeontology, (3rd edition). Chicago University Press.
- Saraswati, P.K. and Srinivasan, M.S. (2016) *Micropaleontology: Principles and Applications*. Cham: Springer International Publishing.
- Seilacher, A. (2007) *Trace Fossil Analysis*. Berlin: Springer-Verlag.
- Sreepat, J. (2017) *Fundamentals of Invertebrate Palaeontology: Microfossils*. New Delhi: Springer India.

Climatology and Planetary Geology

(Full Marks – 75)

Part – A: Climatology

(Full Marks – 40)

Unit 1: Climate system: Forcing and Responses

Components of the climate system.

Climate forcing, Climate controlling factors. Feedbacks in climate system (positive and negative).

Unit 2: Heat budget of Earth

Incoming solar radiation, receipt and storage of heat transformation. Earth's heat budget. Interactions amongst various sources of earth's heat. Effect of CO_2, CH_4, aerosols, ozone, and their roles in climate forcing.

Unit 3: Atmosphere – Hydrosphere

Layering of atmosphere and atmospheric Circulation. Atmosphere and ocean interaction and its effect on climate. Surface and deep circulation. Sea ice and glacial ice.

Major drivers of regional and global climate variability – El Niño-Southern Oscillation (ENSO), the North Atlantic Oscillation (NAO), and the Indian Ocean Dipole (IOD).

Unit 4: Response of biosphere to Earth's climate

Climate change: natural vs. anthropogenic effects. Future perspectives. Brief introduction to archives of climate change. Brief introduction to palaeoclimate. Palaeoclimate data from India.

Unit 5: Human Dimensions of Climate Change

Climate policy, adaptation, and mitigation strategies; Indian context (National Action Plan on Climate Change).

Unit 6: Orbital cyclicity and climate

Milankovitch cycles and variability in the climate. Glacial-interglacial stages. The last glacial maximum (LGM) Pleistocene Glacial-Interglacial cycles.

Unit 7: Monsoon

Mechanism of monsoon. Monsoonal variation through time. Factors associated with monsoonal intensity. Effects of monsoon.

Extreme Weather Events: Causes, frequency, and impacts of cyclones, droughts, heatwaves, and floods, with Indian case studies.

Part – B: Planetary Geology

(Full Marks – 35)

Unit 1: Important space odysseys; Indian space missions.

Unit 2: Surface of Moon, Mars and Venus: Planetary structure, composition and surface processes.

Unit 3: Internal constitution of different planets.

Unit 4: Planetary Magnetism and Dynamo Theories – Origin of planetary magnetic fields and implications for habitability.

Unit 5: Impact craters: Morphology, diversity and origin.

Unit 6: Origin and classification of meteorites.

Unit 7: Tectonic structures on different Terrestrial planets.

Unit 8: Planetary remote sensing: Optical data, hyperspectral data, radar data and their applications.

Unit 9: Concept of crater-based geochronology.

Unit 10: Astrobiology and Search for Life – Conditions for life, biosignatures, and recent findings from Mars and icy moons (Europa, Enceladus).

Reference Books

- Aguado, E., and Burt, J., 2009. Understanding weather and Climate. 5th Edition, Pearson Publisher
- Bender, M. (2013) Paleoclimate, Princeton Premiers in Climate
- Bradley R. S., (1999), Paleoclimatology: Reconstructing climates of the quaternary. Academic Press v. 64 of International Geophysical series.
- Dorothy Merritts, Kirsten Menking and Andrew deWet, 2014. Environmental Geology: An Earth Systems Science Approach. Edition 2, W.H. Freeman and Co Ltd
- Greeley, Ronald. Introduction to planetary geomorphology. Cambridge University Press, 2013.
- Gunter, F. and Teresa, M. M. 2007, Introduction to planetary science: The geological perspective. Springer, the Netherlands. ISBN: 13 978-1-4020-5544-7.
- Lal, D.S. 2011 Climatology, Sharda Pustak Bhawan.

- Lutgens, F., Tarbuck, E., and Tasa, D., 2009. The Atmosphere: An Introduction to Meteorology. Pearson Publisher
- Melosh, J.H. 2012, Planetary Surface Proceses. Cambridge University Press.
- Rohli, R.V., and Vega, A.J., 2007. Climatology. Jones and Barlatt
- Ruddiman, W.F. (2008) Earth's Climate, Past and Future, WH Freeman & Co. Shepherd, Submarine Geology.
- Singh, S. 2020, Climatology.
- Meadows, Victoria, et al., eds. Planetary astrobiology. University of Arizona Press, 2020.
- Watters, T.R. and Schultz, R.A. 2009, Planetary Tectonics. Cambridge University Press.

Statistical Application in Geology

(Full Marks – 50)

Unit-1. Some basic concept of statistics: Population, sample. Measurement - scale & error.

Unit-2. Concept of probability**,** Bayesian Probability.

Unit-3. Population distribution- binomial, normal, Poisson.

Unit-4. Hypothesis testing (i): Concept of a hypothesis, tests involving mean, proportion, standard deviation; concept of *P*-value; Small sampling theory- Chi-square, Student's t, F tests.

Unit-5. Hypothesis testing (ii) ANOVA (one way, two way), correlation & linear regression.

Unit-6. Concept of spatial analysis; Kriging (Simple and Ordinary).

Reference Books

- Bonamente, M., 2016. *Statistics and Analysis of Scientific Data*. 2nd ed. Cham: Springer.
- Davis, J.C., 2002. *Statistics and Data Analysis in Geology*. 3rd ed. New York: John Wiley & Sons.
- Gupta, S.P., 2023. *Statistical Methods*. 45th ed. New Delhi: Sultan Chand & Sons.
- Gun, A.M., Gupta, M.K. and Das Gupta, B., 2013. *Fundamentals of Statistics, Volume I*. Kolkata: World Press Private Ltd.
- Hengl, T., 2009. *A Practical Guide to Geostatistical Mapping*. Luxembourg: European Commission, Joint Research Centre. Available at: https://doi.org/10.13140/RG.2.1.1975.7602
- McKillup, S. and Dyar, M.D., 2010. *Geostatistics Explained: An Introductory Guide for Earth Scientists*. Cambridge: Cambridge University Press.
- Olea, R.A., 1999. *Geostatistics for Engineers and Earth Scientists*. Dordrecht: Springer.
- Pal, S.K., 1985. *Statistics for Geoscientists: Techniques and Applications*. New Delhi: Concept Publishing Company.
- Sarma, D.D., 2009. *Geostatistics with Applications in Earth Sciences*. 2nd ed. Dordrecht: Springer.
- Wackernagel, H., 2003. *Multivariate Geostatistics: An Introduction with Applications*. 3rd ed. Berlin: Springer.
- Webster, R. and Oliver, M.A., 2007. *Geostatistics for Environmental Scientists*. 2nd ed. Chichester: John Wiley & Sons.

Quantitative Petrology

(Full Marks – 50)

Quantitative modelling of partial melting and fractional crystallization using K_d and D. Batch vs. fractional melting equations, AFC (assimilation–fractional crystallization) models. Use of variation diagram to quantify magmatic crystallization. Application of binary and ternary systems in modelling magmatic processes.

Geothermobarometry in Igneous Petrology: Principles and applications in estimating P–T conditions of igneous rock formation.

Estimation of Pressure and Temperature from important models of Geothermobarometry: Garnet-biotite, Garnet-Orthopyroxene, Garnet-Clinopyroxene, Hornblende-Plagioclase, Garnet-Orthopyroxene-Plagioclase-Quartz, Garnet-Sillimanite-Biotite-Quartz methods.

Isotope Geothermometry and Geospeedometry – Principles and examples (O, Sr, Nd isotopes; diffusion-based temperature estimates).

Quantitative Petrology: Basics of Gibbs free energy minimization; introduction to software such as THERMOCALC, Perple_X, or MELTS (free educational package).

Statistical analysis of particle size distribution of clastic sediments.

Analytical Techniques in Earth Sciences

(Full Marks – 50)

Unit 1: Sampling and sample preparation: thin section and polished section making; sample etching; staining and modal count techniques.

Unit 2: Use of analytical spectroscopic methods and chemical analyses.

Unit 3: Analytical Techniques in Earth Sciences: Principles and Applications.

(a) *Thermal Analysis Techniques*: Differential Thermal Analysis (DTA), Thermogravimetric Analysis (TGA);

(b) *X-ray and Electron-based Techniques*: X-ray Diffraction (XRD), X-ray Fluorescence (XRF), Scanning Electron Microscope (SEM); Transmission Electron Microscope (TEM), Electron Probe Micro-Analyzer (EPMA).

(c) *Spectroscopic Methods*: Fourier-Transform Infrared Spectroscopy (FTIR), Raman Spectroscopy.

(d) *Mass Spectrometric Techniques*: Inductively Coupled Plasma Mass Spectrometry (ICP-MS), Secondary Ion Mass Spectrometry (SIMS/Ion Probe),

(e) *Other Techniques in Geochronology and Geochemistry*: Atomic Absorption Spectroscopy (AAS), Optically Stimulated Luminescence (OSL) Dating, Fission Track (FT) Dating;

(f) New emerging techniques.

Unit 4: Basic principles of cathode luminescence imaging.

Unit 5: Use of stable and radioactive isotopes in earth sciences to trace geological processes.

Unit 6: Interpret results from various geological archives, such as sediments or rocks.

Unit 7: Data Interpretation & Limitations.

Reference Books

- Gill, R. (Ed), (1997) Modern Analytical Geochemistry Longman (Pearson Education Limited), 329 pp.
- Goldstein, J.I., Newbury, D.E., Joy, D.C., Lyman, C.E., Echlin, P., Lifshin, E., Sawyer, L.C. and Michael, J.R. (2018) *Scanning Electron Microscopy and X-ray Microanalysis*. 4th edn. New York: Springer.
- Henderson, P. (ed.) (2005) *The Analytical Chemistry of Silicate Rocks*. Cambridge: Cambridge University Press.
- Moore, D.M. and Reynolds, R.C. (1997) *X-ray Diffraction and the Identification and Analysis of Clay Minerals*. 2nd edn. Oxford: Oxford University Press.
- Potts, P.J. (1992) *A Handbook of Silicate Rock Analysis*. London: Blackie Academic & Professional.Reed, S.J.B. (2005) *Electron Microprobe Analysis and Scanning Electron Microscopy in Geology*. 2nd edn. Cambridge: Cambridge University Press.
- Rollinson, H.R. (1993) *Using Geochemical Data: Evaluation, Presentation, Interpretation*. Harlow: Longman.
- Skoog D.A., Holler F.J., and Nieman T.A., (1998) Principles of Instrumental Analysis 5th Ed., Saunders College Publishing, 832 pp.
- White, W.M. (2013) *Geochemistry*. Hoboken, NJ: Wiley-Blackwell.
- Wilson, M.J. (1994) *Clay Mineralogy: Spectroscopic and Chemical Determinative Methods*. London: Chapman & Hall.

Computer Application in Geology

(Full Marks – 50)

- Spreadsheet Application. Important functions and calculations. Chart preparation.
- Statistical analysis using Excel.
- Use of Graphics software and image processing tools (GIMP, ImageJ).
- Use of Exploration Geology/Engineering Geology Software.
- Mineralogical and petrological data handling software (GCDkit.Mineral and other software).
- Introduction to the use of R for statistical computing and graphics.
- Python/C for Geoscience – Basic idea of the use of Python/C for statistical analysis.

Reference Books

- Adler, J. (2012) *R in a Nutshell: A Desktop Quick Reference*. 2nd edn. Sebastopol, CA: O'Reilly Media.
- Crawley, M.J. (2013) *The R Book*. 2nd edn. Chichester: Wiley.
- GoSkills. (n.d.). The Ultimate Guide to Excel Charts. Available at: https://www.goskills.com/Excel/Resources/Excel-charts

- Janoušek, V., Farrow, C. M., & Erban, V. (2016). GCDkit. Mineral: A customizable, platform-independent R-language environment for recalculation, plotting, and classification of electron microprobe data. *Computers & Geosciences*, *90*, 29-37.
- Janoušek, V., Farrow, C.M. and Erban, V. (2006) *Interpretation of Whole-Rock Geochemical Data in Igneous Geochemistry: Introducing Geochemical Data Toolkit (GCDkit)*. *Journal of Petrology*, 47(6), pp.1255–1259.
- Kabacoff, R.I. (2015) *R in Action: Data Analysis and Graphics with R*. 2nd edn. Shelter Island, NY: Manning Publications.
- Kanetkar, Yashavant. Data Structures Through C: Learn the fundamentals of Data Structures through C. BPB Publications, 2019.
- Kanetkar, Yashavant P. Let us C. BPB publications, 2004.
- Moon, C.J., Whateley, M.K.G. and Evans, A.M. (2006) *Introduction to Mineral Exploration*. 2nd edn. Oxford: Blackwell Publishing.
- Peck, C. (2019) *GIMP 2.10 for Photographers: Image Editing with Open Source Software*. Rocky Nook.
- Reding, E.E., Wermers, L. and Cram, C. (2019) *Microsoft Excel 2019 Comprehensive*. Boston, MA: Cengage Learning.
- Rollinson, H. (2021) *Using Geochemical Data: Evaluation, Presentation, Interpretation*. 2nd edn. London: Routledge.
- Schneider, C.A., Rasband, W.S. and Eliceiri, K.W. (2012) *NIH Image to ImageJ: 25 years of image analysis*. *Nature Methods*, 9(7), pp.671–675.
- Suman, H. (n.d.). *Excel Formulas and Functions: The Complete Excel Guide For Beginners*. Excel Master Consultant.
- Sundarrajan M, Choudhry M.D., Jeevanandham S, Jothi A. (2024) *Python Programming: Beginners Guide*, ISBN: 979-8893636963
- Walkenbach, J. (2015) *Excel 2016 Bible*. Indianapolis: John Wiley & Sons.
- Winston, W.L. (2016) *Microsoft Excel 2016 Data Analysis and Business Modeling*. Redmond, WA: Microsoft Press.
- Wickham, H., & Grolemund, G. (2017). *R for Data Science: Import, Tidy, Transform, Visualize, and Model Data*. O'Reilly Media.

Earth Science Colloquium

(Full Marks – 100)

(Project/ Presentation – 75 | Viva – 25)

Compulsory seminar presentation and report writing by students on geologically important themes based on published papers.

The presentation is related to dissertation thesis for Honours with research students.

Evaluation will be based on seminar performance, report, and a viva-voce examination.

Dissertation Thesis

(Full Marks – 200)

(Written – 150 | Viva – 50)

This course is designed to equip students with the essential skills required for conducting geological research, as well as the methodology of writing a thesis and preparing research publications.

The *Dissertation Thesis* will be evaluated based on:

- The *thesis/project report* submitted to the department (considered as the written component), and
- An *oral presentation* followed by a *viva-voce examination.*

Introductory soil science and Natural Hazards

(Full Marks – 50)

Unit 1: Soil forming processes: Chemical weathering, major buffer maintaining ocean/atmosphere/biosphere O_2 and CO_2, new compounds/minerals of greater volume and lower density; Oxidation; Carbonation; Hydrolysis; Hydration; Base Exchange; Chelation; Microbial weathering.

Soil forming processes: Physical weathering, loosening and particle size reduction; pressure release; thermal expansion; growth of foreign crystal.

Unit 2: General soil forming regimes: Gleization; podzolization; lessivage; ferrallitizatin; calcification; salinization.

Unit 3: Introduction to Soil Mechanics: Basic definitions, Origin and formation of soils, Rock cycle, Weathering of rock.

Unit 4: Study of Soil: Soil particle size, Clay minerals, Soil structure, Mechanical analysis of soil, Particle size distribution, Sieve analysis & Hydrometer analysis.

Weight Volume Relationships, Components of soil and phase diagram, Definitions of void ratio, porosity, specific gravity, unit weights/density, and degree of saturation.

Various unit-weight relationship, Relative density, Atterberg's limits and indices, Activity, Plasticity chart.

Stress distribution in Soils, Type of stresses in soil, Effective stress concept, Effect of water table fluctuation on effective stress, Effects of seepage and capillarity on effective stress.

Unit 5: Natural Hazards: The Lithosphere and Related Hazards Atmospheric Hazards, Hydrosphere and Related Hazards.

Unit 6: Disaster Management: Issues and concern for various causes of disasters. Disaster management, mitigation, and preparedness.

Types of disaster: natural and manmade – cyclone, flood, land slide/mass movement, land subsidence, fire and earthquake, tsunami and volcanic eruption.

Unit 7: Disaster Management in India: Hazard Zonation Mapping; Vulnerability and risk assessment frameworks.

Early Warning Systems & Technology: Remote-sensing and GIS, GPS, drones, and AI in hazard monitoring. Real-time seismic and flood warning systems.

Prevention and rehabilitation.

Unit 8: India-specific Case Studies: India-specific case studies on Earthquakes, Tsunamis, Landslides, Glacier Disasters, Floods & Flash Floods, Droughts and Cyclones. Disaster management plans and methodologies.

Unit 9: Disaster Policy and Legal Framework in India: Disaster Management Act (2005). Role of National Disaster Management Authority (NDMA). Sendai Framework for Disaster Risk Reduction (2015–2030).

Reference Books

Group – A

- Ashman M.R. and Puri G., 2002, Essential Soil Science, Blackwell.
- Buol, S.W., Hole, F.D. and McCracken, R.J. (2011) *Soil genesis and classification*. 6th ed. Ames, IA: Iowa State University Press.
- Brady, N.C. and Weil, R.R. (2017) *The nature and properties of soils*. 15th ed. Columbus, OH: Pearson Education.
- Chesworth, W. (2008) *Encyclopedia of soil science*. Dordrecht: Springer.
- Jenny, H. (1994) *Factors of soil formation: a system of quantitative pedology*. New York: Dover Publications.
- Jothimani, S. 2022, Text book of Soil Science for Agriculture and Geology, 230p. ISBN: 978-93-93502-05-6
- Lal, R. & Shukla, M.K., 2004. *Principles of Soil Physics*. Marcel Dekker, New York.
- Palmer, Robert G. and Troeh, Frederick R. 1995, Introductory Soil Science Laboratory Manual, 3rd Ed., Oxford University Press.
- Retallack, G.J. (2008) *Paleopedology: Pedogenetic Processes and Paleoenvironments*. Oxford University Press.

Group – B

- Alexander, D. (2000) *Confronting Catastrophe: New Perspectives on Natural Disasters*. Terra Publishing.
- Bryant, E. (2005) *Natural Hazards*. 2nd edn. Cambridge University Press.
- Bell, F.G. (1999) Geological Hazards, Routledge, London.
- Coppola, D.P., 2020. *Introduction to International Disaster Management*. 4th ed. Butterworth-Heinemann, Oxford.
- Gupta, H.K. (2007) *2004 Sumatra Earthquake and Indian Ocean Tsunami: A Scientific Perspective*. Capital Publishing Company.
- Gupta, H.K. (2003) *Disaster management*. Hyderabad: Universities Press.
- Keller, E.A., DeVecchio, D.E. & Clague, J.J., 2016. *Natural Hazards: Earth's Processes as Hazards, Disasters, and Catastrophes*. 4th ed. Routledge, London.
- Keller, Edward A. 2017, Introduction to Environmental Geology, 5th Ed., Pearson.

- Montgomery, Carla W. 2011, Environmental Geology, 9th ed., McGraw-Hill
- NDMA (2005) *Disaster Management Act*. New Delhi: Government of India. Available at: https://ndma.gov.in
- Sharma, V.K., 2011. *Disaster Management*. National Book Trust, New Delhi. OR Sharma, V.K. (2001) *Disaster management*. New Delhi: National Centre for Disaster Management.
- Smith, K. (2013) *Environmental hazards: assessing risk and reducing disaster*. 6th edn. London: Routledge.
- UNDRR (2015) *Sendai Framework for Disaster Risk Reduction 2015–2030*. Geneva: United Nations Office for Disaster Risk Reduction.
- Valdiya, K.S., 1987. *Environmental Geology: Indian Context*. Tata McGraw-Hill, New Delhi.

Sustainable Watershed Management and Medical Geology

(Full Marks – 50)

Unit-1: Introduction

Watershed – definition, concept, objectives; watershed controls, Water demand and availability; Surface Water-Groundwater interactions, Conjunctive use, Conflicts over water.

Unit-2: Hydrology and Meteorological Factors

Concepts of drainage basin, groundwater basin; water balance. Land cover and landuse maps; effects of landuse on hydrological components, Land capability and suitability classification; priority watersheds.

Meteorological (temperature, wind speed, sunshine hours, atmospheric pressure, relative humidity) and hydrological (suspended sediment and bed load) parameters; Crop water management.

Unit-3: Watershed Conservation Practices

Moisture and soil conservation in irrigated lands, dry lands, arid and semi-arid regions; Water management through wells, water supply, wastewater recycle and reuse, Control measures for air and soil erosion – vegetative and mechanical for agricultural and non-agricultural lands; Temporary & Permanent gully control measures; Micro-catchment water harvesting structures; Groundwater recharge – percolation ponds, water harvesting, roof catchment system, check dams, aquifer storage; Farm ponds, Supplementary irrigation, Evaporation suppression, Seepage reduction, rainwater storage and effective utilisation, Case studies.

Unit-4: Watershed and Society

Social Aspects of Watershed Management: Community response to watershed degradation; Community participation in Watershed restoration, Private-Public participation, Water legislation, Institutional issues, Role of NGOs in watershed development, Watershed based rural and infrastructure development; Role of Decision Support System in Watershed Management; Case studies.

Unit-5: Watershed Planning and Policy Issues

Planning principles; Monitoring and evaluation system; short and long term strategic planning and development. Important watersheds of India - River Valley Projects (RVP), Hill Area

Development Programme (HADP), National Watershed Development Programme for Rain-fed Agriculture (NWDPRA); Wetland and Ramsar Convention; National guidelines.

Unit-6: Watershed Management and Sustainability

Watershed: From Unsustainable to Sustainable Approach; Watershed-environment relationship Integrating watershed with natural resource management, Effects of Climate Change on Watershed; Concept of bio-village and integrated farming, water budget, Inter-basin Water Transfer; application of RS-GIS and drone technology in Watershed Management.

Unit-7: Medical Geology and Etiology of Diseases

Foundation of Medical Geology, Environmental classification of elements; Distribution and geochemical distribution of major environmental elements; Biogeochemical cycles; Bioavailability of elements and etiology of diseases.

Study of Aerosols; National and international public health standards; Geochemical baselines.

Case studies: source, pathways, sinks and public health effects of U, Th, REE, Radon, As, Fe, Se, I, NO_3.

Reference Books

- Brooks K.N., Folliott P.F. and Magner J.A., 2012, Hydrology and the Management of Watersheds, 4th Ed., John Wiley & Sons, ISBN: 978-0-470-96305-0
- Debarry P.A., 2004, Watersheds: Processes, Assessment and Management, Wiley, 720p.
- Dissanayake C. B. and Chandrajith R., 2009, Introduction to Medical Geology, Springer-Verlag
- Gonenc I.E., Vadineanu A. and Wolflin J.P., 2008, Sustainable Use and Development of Watersheds, Springer
- Heathcote I.W., 2009, Integrated Watershed Management: Principles and Practice, John Wiley & Sons Ltd., 464p. ISBN: 978-0-470-37625-6
- Murthy J.V.S., 2017, Watershed Management, 2nd Ed., New Age International Publisher
- Naiman, R.J. 1992, Watershed Management: Balancing Sustainability and Environmental Change, Springer, 542 pp. ISBN 0-387-97790-2
- Selinus, Olle (Ed.), 2013, Essential of Medical Geology: Impacts of the Natural Environment on Public Health, Revised Edition. Springer.

Earth Systems Science

(Full Marks – 50)

Geology: Definitions and Scope.

Internal structure of the Earth: Earth's materials, minerals and rocks: Broad groups of minerals, oxides, sulphides, carbonates, sulphates and phosphates, silicates. Rocks as mineral assemblages, fabric, texture. Classification of rocks. Igneous rocks; types: acid, intermediate, mafic and ultramafic rocks. Sedimentary rocks; types: clastic and non-clastic. Metamorphic rocks; types: foliated, nonfoliated.

Structure of geologic bodies: Extrusive and intrusive igneous rock bodies, lava flows, sills, dykes, batholiths. Bed and stratum, dip and strike. Folds, antiform, synform, anticline, syncline. Fractures, joints and faults. Foliation, lineation.

The fossil record: Fossils as evidence of past life. Modes of preservation of fossils. Uses of fossils.

Gravity and gravity anomaly on Earth: Bouguer and Free-air anomaly. Concept of isostasy and compensation, hypotheses of Airy and Pratt.

Elementary idea of theory of plate tectonics: Basic concepts and geological evidences of continental drift, sea-floor spreading and plate tectonics. Lithosphere, asthenosphere. Plates and plate boundaries, relative motion of plates. Present day configuration of plates. Mid-oceanic ridges, oceanic islands and trenches, hot spots and aseismic ridges. Volcanism and plate tectonics, earthquakes and plate tectonics, continental margins and their evolution. Life cycles of oceans.

Earth's internal processes: Magmatism, Volcanism types of eruption.

Earthquakes: Causes, elastic rebound theory, focus and epicentre, intensity and magnitude. Seismic waves, seismograms, travel-time curves for seismic waves, seismic discontinuities, locating epicentre, and determining magnitude. Earthquake belts. Effects of earthquakes, seismic zones of India.

Project work: Earth Systems Science

(Full Marks – 50)

Project work on:

Study of minerals in hand specimens.

Study of rocks in hand specimen.

Reference Books

- Mahapatra, G.B., 1994. A text book of Physical geology. CBS Publishers.
- Singh P. Engineering Geology, Kataria Publication.

Artificial Intelligence

(AI for Everyone: CU Notification No: CSR/36/2023)

Unit 1: Introduction to Artificial Intelligence (6 Lectures)

Definition and scope of AI.

Historical overview and key milestones.

Differentiating AI from human intelligence.

Unit 2: AI Subfields and Technologies (6 Lectures)

Machine learning: Supervised, unsupervised, and reinforcement learning.

Deep learning and neural networks.

Natural language processing (NLP) and computer vision.

Unit 3: Applications of AI (8 Lectures)

AI in healthcare: Diagnosis, treatment, and medical imaging.

AI in finance: Fraud detection, algorithmic trading, and risk assessment.

AI in transportation: Autonomous vehicles and traffic optimization.

AI in customer service and chatbots.

AI in education: Personalized learning and intelligent tutoring systems.

Unit 4: Ethical and Social Implications of AI (5 Lectures)

Bias and fairness in AI systems.

Privacy and data protection concerns.

Impact of AI on employment and the workforce.

AI and social inequality.

Unit 5: Other Important Issues

Ethical guidelines and responsible AI practices.

AI and Innovation.

Emerging trends and future directions in AI.

AI and creativity: Generative models and artistic applications.